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Sealing the Borders

The Effects of Increased Military Participation in Drug Interdiction

Peter Reuter, Gordon Crawford,
Jonathan Cave

40 Years 1948-1988

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Rising concern with drug use in the United States has led to increased emphasis on the interdiction of drugs before they reach the country. The military services are now being asked to assume a substantial share of the burden of this interdiction. This report analyzes the consequences of greater stringency in drug interdiction efforts, focusing particularly on how such increased stringency might influence the consumption of cocaine and marijuana. The analysis strongly suggests that a major increase in interdiction activities, even including the military, is unlikely to significantly reduce drug consumption in the United States. (See also N-2632 and N-2680.)

Keywords: Drug trafficking; smuggling; Law enforcement; (KT)

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Sealing the Borders

The Effects of Increased Military Participation in Drug Interdiction

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Prepared for the
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for Policy

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PREFACE

Rising concern with drug use in the United States has led to increased emphasis on the interdiction of drugs before they reach this country. The military services are now being asked to assume a substantial share of the burden of this interdiction.

In light of this development, the Office of the Under Secretary of Defense for Policy requested that RAND carry out an analysis of the consequences of further increases in the military involvement in drug interdiction efforts, focusing particularly on how this involvement might influence the consumption of cocaine and marijuana. This report presents the results of that analysis. Supporting research is presented in two companion RAND Notes, which describe models developed within the study:

> Jonathan Cave and Peter Reuter, *The Interdictor's Lot: A Dynamic Model of the Market for Drug Smuggling Services*, N-2632-USDP, February 1988.
>
> Gordon Crawford and Peter Reuter, *Simulation of Adaptive Response: A Model of Drug Interdiction*, N-2680-USDP, February 1988.

This report was prepared within RAND's National Defense Research Institute, a Federally Funded Research and Development Center supported by the Office of the Secretary of Defense. It is a product of RAND's program in International Security and Defense and should be of interest to policymakers and researchers concerned with efforts to control drug smuggling.

SUMMARY

BACKGROUND

As concern about illicit drug use in America has grown over the past decade, increased emphasis has been placed on interdiction of imported drugs, particularly marijuana and cocaine. Interdiction, the seizure of drugs and smugglers as they travel from the source countries to the United States, now constitutes 38 percent of the expanded federal drug enforcement program. Despite these expenditures, interdiction appears to remain relatively ineffective, as the flow of cocaine imports increases at ever lower prices.

Disappointment with the results of the interdiction program has led to an interest in using the resources of the military services for drug interdiction. Indeed, the Congress has given serious consideration to a bill that would have made the Department of Defense (DoD) the primary interdiction agency. This report presents the principal findings of a study of the likely effects of increased military involvement in the drug interdiction effort.

The study was limited to the interdiction of marijuana and cocaine; the third major imported drug, heroin, was not examined because heroin smuggling does not appear to be amenable to the kind of interdiction activity the military services can enhance.

ANALYTIC APPROACH

Interdiction affects the use of illicit drugs by raising the risks faced by drug smugglers. Removals of drugs (i.e., seizures) do not of themselves lessen the availability of drugs, at least not of marijuana and cocaine, for which there is a large established base of production, importation, and distribution. But as the risks of losing drugs and having agents arrested rise, smugglers incur higher expenses. These in turn produce higher import prices, which eventually raise the price paid by the drug user. Price increases are the principal means by which interdiction can affect use, although some users may be relatively insensitive to price.

Smugglers may adapt to increased interdiction efforts in a number of ways. They may accept higher rates of drug loss or find more expensive but lower risk means of importation. There is evidence that such adaptation has been significant in recent years. For example,

marijuana smugglers, faced with a significant marine interdiction program for Colombian-source marijuana, seem to have shifted to Mexican and domestically produced marijuana. This kind of adaptation makes clear that the interdiction rate and the quantity seized are flawed indicators of interdiction effectiveness.

The principal evaluative criterion for the impact of increased interdiction effort in this study is the effect such effort has on the difference between import and export prices. This approach is not without its limitations, as briefly discussed here, but it does capture the major effects of interdiction on drug use.

One problem is that changes in smuggling risks and quantities seized also influence the export price of drugs. If, as seems highly likely, the demand for marijuana and cocaine is relatively insensitive to the import price, then increases in the percentage of drugs seized will tend to increase total export demand (reflected in both price and quantity), which includes both drugs successfully delivered and drugs that are seized. Thus, we conclude that cocaine interdiction has probably increased the export earnings of producers in Bolivia, Colombia, and Peru. On the other hand, interdiction programs that lead smugglers to adopt more covert and expensive methods of smuggling will reduce total export demand. For this reason, and because of the growth of domestic production, marijuana interdiction has probably reduced both export prices and export quantities of that drug. Since the export price of marijuana is less than 5 percent of the import price, this will not appreciably decrease the validity of our criterion; even if interdiction halved the export price, it would raise the import-export price margin by only 2.5 percent.

THE DRUG INTERDICTION PROGRAM

Drug interdiction is carried out primarily by three agencies: The Coast Guard, an agency within the Department of Transportation, provides marine interdiction, aimed primarily at marijuana smuggling. The Customs Service provides inshore marine coastal, as well as air and land, interdiction, encompassing both cocaine and marijuana. The Immigration and Naturalization Service (INS) is now also a major land border interdiction agency, though its drug seizures still constitute a modest share of total seizures.

From 1981 to 1986, annual nonmilitary expenditures on interdiction increased from $263 million to $605 million. Seizures of cocaine rose much faster, from less than 2 metric tons in 1981 to over 25 metric tons in 1985. At the same time, marijuana seizures declined, from

4,000 metric tons in 1981 to 2,000 metric tons in 1985. Official estimates of total quantities imported also changed over the same period. Cocaine imports are estimated to have risen 150 percent, while marijuana imports are estimated to have remained almost constant. Marijuana imports may have been significantly affected by the expansion of the domestic supply of marijuana.

The little available data show a sharp decline in the price of cocaine at the import level, and very probably at the retail level. Marijuana prices have a less clear-cut pattern. Import prices have probably fluctuated around a level trend, while retail prices may have risen somewhat; increased potency of the recent crops makes it difficult to determine whether this has been an increase in effective price.

Effective drug interdiction requires a combination of factors to produce seizures and arrests. Whether by land, air, or sea, interdiction agencies must detect "targets" crossing or attempting to cross U.S. borders; identify which of these targets could be smugglers; and intercept those suspects to determine whether or not they are transporting drugs. Catching a smuggler requires success in each of these components. Simply increasing the resources to perform one aspect of the interdiction function does not guarantee an increase in the interdiction rate. For example, the Coast Guard could be given the resources to detect twice as many vessels as it currently does, but without an appropriate increase in sorting and interception capabilities, the interdiction rate will not double.

Law enforcement officers who have access to prior information regarding a smuggler can increase their probability of detecting, identifying, or intercepting him. Such prior information, or intelligence, removes some of the randomness in interdiction activities and can sharply increase the effectiveness of the available resources. On the high seas, a variety of vessels can be used by smugglers, each of them difficult to distinguish from legitimate traffic. Coast Guard data have indicated that a substantial share of maritime interceptions of smugglers have been the result of intelligence reports. Even with the benefit of intelligence, the sorting process can be difficult. Only one out of every eight vessels the Coast Guard boarded, with prior information suggesting that the ships might be carrying drugs, was actually smuggling.

Air interdiction has realized little benefit from intelligence. While an oceangoing vessel is vulnerable to interdiction for a relatively long period of time, an airplane flying drugs over the Mexican border is in the air for only an hour or two. When law enforcement officials receive information regarding an air smuggler, the plane could be in U.S. airspace for as little as 30 minutes prior to unloading. Once

launched on its return trip, it cannot be stopped. Given this limited window of vulnerability, increased intelligence will do little to enhance the effectiveness of air interdiction.

The military services have provided support to drug interdiction activities since 1971. Recent changes in the Posse Comitatus Act (18 U.S.C. 1385) have led to a substantial increase in the level of support. The estimated DoD expenditures on interdiction have risen from $1 million in fiscal year 1981 to $196 million in fiscal year 1986.

Most of the military interdiction effort has taken the form of providing surveillance services, particularly airborne radar, e.g., AWACS (advanced warning and control systems) and E-2s. Some resources have been devoted to augmenting maritime and air pursuit capabilities. Military personnel are subject to legal restrictions that prevent the services from becoming primary interdiction agencies. Moreover, interdiction is still a secondary mission for most units, although the Congress has recently mandated that the services acquire certain assets to be dedicated to this activity.

The military contributions are provided in response to requests by the primary interdiction agencies. The vast majority of such requests have been met. However, the services have until recently not provided the agencies with lists of relevant equipment and personnel capabilities. Provision of such lists, now required under the Omnibus Drug Control Act of 1986 (HR 5484), may increase agency demands for military support.

The fact that the DoD is a support rather than a primary interdiction agency means that military contributions must be integrated with those of the three primary agencies. Some of the contributions provided in the past, such as AWACS missions, seem not to have been very useful because of the lack of integration.

MODELING SMUGGLERS' ADAPTATION TO INCREASED INTERDICTION EFFORTS

Smugglers have many choices with respect to the methods used for importing marijuana and cocaine. They may vary geographic routes, types of transportation, time of entry, modes of concealment, etc. Their choices are affected by costs and risks. As interdiction agencies increase the risks associated with one route or mode, for example, smugglers will be motivated to shift more of their activity toward other routes and modes.

Prior analyses of the impact of increasing interdiction resources have not allowed for adaptation by smugglers. Therefore, these

analyses probably overestimated the consequences of, for example, improving surveillance capabilities in southern Florida.

To capture the impact of adaptation on the effectiveness of increasing interdiction resources, we have developed a simulation model, called SOAR (Simulation of Adaptive Response). In SOAR, smugglers estimate the risks of particular forms of smuggling by observing the interdiction rates associated with them. In this model, the interdiction agencies lead, with the smugglers lagging and adapting only through experience.

In the initial runs of SOAR, smugglers as a group attempt to bring in a fixed quantity of drugs at minimum aggregate cost. Their costs include compensation for their agents (pilots, boat crew members, etc.) for incurring the risk of being arrested and imprisoned, as well as replacement of drugs and transportation equipment and training of new agents. Risk compensation payments are assumed to rise more than proportionately with risk.

Using the available data, and making many judgmental estimates about relevant parameters, we have simulated the impact of raising the probability of interdiction along different routes by using additional military resources. The results show that even though quantities seized rise sharply as an increasing number of routes become very risky, the aggregate cost of getting the drugs from the source country to the United States rises only modestly, particularly when compared with the total cost of drugs to the users. For example, when five of eleven possible routes become subject to an interception rate of 0.5 rather than the baseline 0.2, total cocaine smuggling costs rise by 38 percent, while total seizures rise 58 percent. But this constitutes only about a 4 percent increase in the cost of getting cocaine to the final user. Even when ten of the routes are subject to the higher interdiction rate, the rise in smugglers' costs (70 percent above the baseline level) adds less than 10 percent to the cost of delivery to final users.

This first set of SOAR runs assumed a fixed quantity of imports and focused simply on aggregate smuggler costs. A second set of runs, using output from the initial runs, incorporates the effects of feedbacks from total shipments to the export price of drugs and from increases in import prices to reduced total consumption. The results again suggest the difficulty of significantly reducing cocaine consumption through interdiction. When five of the eleven routes have a 0.5 probability of interdiction, consumption falls only by 15 percent. With ten routes subject to the higher rate, consumption falls by 25 percent. The results for cocaine smuggling are summarized in Fig. S.1.

Interdiction was found to have stronger effects on imports of marijuana, reflecting the fact that the replacement cost of the drug is a

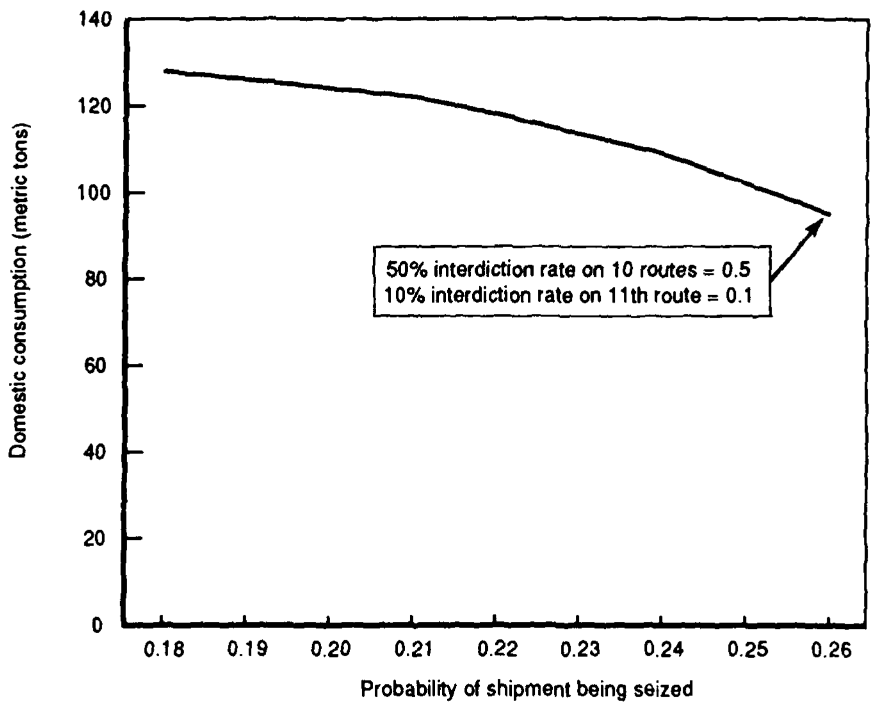

Fig. S.1—Interdiction rates and domestic consumption

smaller share of total smuggler costs. With five routes subject to the 0.5 interdiction rate, marijuana smuggling costs rose 83 percent, while seizures rose 66 percent. When ten routes are subject to a 0.5 interdiction rate, costs rise 66 percent, while seizures rise 97 percent. In the latter case, the increase in prices causes a 60 percent reduction in consumption. Unfortunately, we were not able to incorporate explicitly a domestic production sector, a factor which limits the impact of higher smuggling costs on total consumption.

Another phenomenon that may lower the effectiveness of interdiction, i.e., learning (as opposed to adaptation) on the part of smugglers, is also not incorporated in SOAR. A theoretical model of the effect of learning is presented, however, which assumes that the accumulation of experience by a smuggler leads to a reduction in his risk, and hence his costs. As the population of smugglers becomes more experienced in the aggregate, the market supply curve shifts out, i.e., more drugs are supplied at a lower landed price. This model again shows the dangers of using data on seizures as the criterion for evaluating interdiction efficacy.

CONCLUSIONS

Increased drug interdiction efforts are not likely to greatly affect the availability of cocaine in the United States. This conclusion is driven primarily by the small share of total drug distribution costs that are accounted for by the smuggling sector. Only about 10 percent of the final price of cocaine comes from smuggling costs and profits. Unless interdiction can very substantially increase the costs of smuggling, more effective interdiction will have modest effects on total cocaine consumption.

For marijuana, the conclusion is somewhat less strong. Interdiction has clearly had an impact on the level of imports from countries other than Mexico. It is possible that using military assets to raise the probability of detection of seaborne marijuana could further raise the price of the drug. However, the vulnerability of the Mexican border and the strength of the domestic industry, as well as the impact of increased potency of recent crops, may greatly mitigate the impact of improved maritime interdiction.

The Department of Defense as an Interdiction Agency

Despite its increasing expenditures in support of drug interdiction, the DoD remains a support agency rather than a primary interdiction agency. Its activities can enhance those of the primary agencies (the Coast Guard, the Customs Service, and the INS), but it cannot substitute for them.

For one thing, military efforts are constrained by legal restrictions. Even with the relaxation of the Posse Comitatus Act, autonomous interdiction activities by military personnel are still subject to numerous restrictions. Most significantly, military personnel do not have arrest powers. As a matter of historical doctrine, there is considerable uneasiness about the use of the military for civilian police functions, and it seems unlikely that this legal restriction will be relaxed in the near future.

In addition, interdiction is a secondary activity for military units. In some cases—for example, the Army training exercises at Fort Huachuca—there is a close fit between military and drug interdiction missions. But in many other cases, such as the use of AWACS, there is some conflict between the primary military mission and drug interdiction.

The Relationship Between Military Support and Drug Interdiction

Military support is largely responsive. Individual agencies make requests of the military for resources. The vast majority of such requests have, so far, been honored. Does that suggest that enough military resources are available to the interdiction agencies?

If it is accepted that the proper military role is to support the activities of other agencies, the answer is apparently positive. Additional military resources that are not used by the primary agencies will be relatively unproductive in drug interdiction. Dedicating military interception aircraft to drug interdiction has little value if the agencies cannot generate enough targets to make use of these aircraft. Flying surveillance missions when no interception aircraft are available to respond to the additional sightings generated by the missions is unlikely to be a productive use of resources.

On the other hand, the volume of requests from interdiction agencies may not be a perfect measure of the utility of military resources. Such requests are made when an agency has a need *and knows that resources are likely to be available.* The high response rate to interdiction agency requests may simply mean that those agencies are aware that relatively little is available from the services. There may also be informal negotiation before formal requests are made.

If, however, the military services were to aggressively "advertise" the availability of their resources, they might generate more requests, which they could indeed satisfy with additional resources. The reluctance of the military to provide lists of relevant capabilities to the interdiction agencies suggests an awareness that such lists might have that very effect. The requirement of the Omnibus Drug Control Act for the preparation of an inventory of capabilities and a plan for their utilization will help to determine just how responsive the interdiction agencies are to a knowledge of what is available.

A striking feature of the interdiction agency performance data is their low rate of successful identification. The Coast Guard success rate with boardings is extremely low, largely because drug vessels are so lacking in distinguishing features. Only 4 percent of boarded vessels turned out to be carrying drugs. When prior intelligence indicated the possibility that a vessel was carrying drugs, the fraction of successful boardings rose, but still only to about 12 percent.

If, as appears to be the case for marine interdiction, the primary capability offered by the military services is to increase the number of potential targets, the Coast Guard experience suggests that this will not add greatly to its effectiveness. At present, the Coast Guard

boards only a small percentage of the vessels it identifies, which in turn is a small percentage of the total it detects. Adding the capability to detect and identify more vessels through patrol is not likely to greatly increase the number of seizures made unless the numbers boarded rise dramatically, an unlikely result given the deployment of Navy resources.

The Consequences of Greater Military Involvement

We believe that the critical issue is whether the military can significantly increase the effectiveness of interdiction at the Mexican border. The border is presently very vulnerable to both land and air smuggling. The weakness of the air interdiction effort has been the subject of considerable concern and a substantial portion of the military expenditure for drug interdiction in fiscal year 1987 is intended to remedy this weakness.

Tethered aerostats are being acquired this fiscal year, which may significantly increase the number of sightings of small planes crossing the border. But it is not at all clear that this will have much effect on the success of the interdiction program, because the probability of correctly identifying smugglers is low and the air pursuit system will still have very limited capacity.

For example, it appears that the San Diego Air Branch of Customs generally limits itself to pursuit of intelligence-identified targets. It lacks adequate means of sorting among the many radar sightings to identify high-probability targets. Better surveillance will significantly augment its efforts only if (1) many current smugglers are avoiding radar sighting, and (2) they are unable to effectively blend in with the traffic once they learn that previously unsurveilled routes are being covered by radar. Given the number of methods for blending into legitimate traffic in high-density areas (such as the area around San Diego), it is difficult to be optimistic about the potential impact of better surveillance.

Land smuggling over the U.S.-Mexico border and smuggling through ports of entry also present major problems. The land border is difficult to control against entry by individuals, who can carry high-value shipments of cocaine; the continuing influx of illegal aliens illustrates this difficulty. Given the need to maintain a smooth flow of commerce across the border, there is considerable reluctance to impose very strict inspection on much of the traffic flowing through ports of entry. Thus increased military contributions to the cocaine interdiction program could be largely negated by a shift to land and port-of-entry smuggling.

This analysis does not conclude that the military should cease to support the drug interdiction program. It strongly suggests, though, that the services cannot be primary interdiction agencies and that a major increase in military support is unlikely to significantly reduce drug consumption in the United States.

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CONTENTS

FIGURES

TABLES

I. INTRODUCTION

The importation of drugs into this country has been treated as a serious public policy problem for almost two decades.[1] An increasingly important part of the response to that problem has been drug interdiction, the seizure of drugs as they journey between the source countries and the United States.[2] Federal agencies have been given enlarged authority and resources for the interdiction program. It now constitutes the largest single component of the rapidly growing federal drug enforcement effort.

Interdiction has several objectives, which have been variously stated. In 1986, the President's Commission on Organized Crime (PCOC) stressed "the maintenance of persistent pressure on drug traffickers, both as a deterrent and as a symbol of national determination" (p. 465). The National Drug Enforcement Policy Board (1986) asserted that "the primary objective of drug interdiction is to substantially reduce the availability of illegal drugs in the United States by limiting the flow of drugs smuggled into this country, through seizures of drugs and through deterrence of potential drug smugglers" (p. 121).

Though both of these are very high-level statements, not intended to provide evaluation criteria, they suggest that interdiction works on the availability of drugs primarily through deterrence of smuggling activity. Interdiction cannot prevent the delivery of some quantity of a particular drug to this country. Most drugs seized through interdiction are replaced, albeit at higher cost. Interdiction attempts to reduce the availability of drugs in the United States by altering the behavior of actual and potential violators through increases in the various risks and costs associated with smuggling. Drug seizure is only one component of the risks that enforcement can create for smugglers and their agents. In this respect, it is like most other law enforcement programs. Enforcement cannot prevent the occurrence of violations. Though it

[1]In the early part of this century, there was considerable concern about the use of imported drugs (Musto, 1973), particularly opium and cocaine. Then there was a hiatus from about the mid-1930s until 1969, when a rapid growth in the heroin addict population brought about renewed concern.

[2]The term *interdiction* can be used broadly to cover any effort to seize drugs and couriers in the distribution process. However, we reserve the term for those programs that focus on drugs in transit from source countries to the United States; this is the common usage in official documents, such as the President's Commission on Organized Crime (1986). Much of the analytic framework presented here can be used for the more general concept of interdiction.

may incapacitate some violators, enforcement works in large part through raising the expected cost of a violation.

The PCOC statement also makes clear that the objectives of interdiction are broader than mere deterrence of drug smugglers. Interdiction provides a highly visible sign to other nations of U.S. interest in reducing drug use. It is possible that a successful interdiction effort will increase the willingness of source countries to make greater efforts to reduce their exports of drugs. However, there is little evidence that source-country programs have had much success (Lee, 1985–86; Reuter, 1985) or that interdiction has the intended effect on political decisions in those countries. Appendix A presents an analysis which suggests that increased interdiction efforts may even, under quite plausible circumstances, increase source-country production incomes.

STUDY OBJECTIVES

The Department of Defense (DoD) has become significantly involved in the interdiction program in the past two years. The Congress considered, and the House of Representatives passed, a bill that would have required the military to assume prime responsibility for "sealing the borders" (Morrisson, 1986). Although this bill was eventually rejected, the Congress has required the DoD to play a larger role in interdiction in support of the primary agencies—the Coast Guard, the Customs Service, and the Immigration and Naturalization Service (INS).

Increasing the role of the military in interdiction raises three major concerns.[3] The first is that involvement in drug interdiction will significantly affect the ability of the military services to carry out their primary mission. Mission compatibility is not an issue that we can readily address, since it requires complex judgments about the uses to which assets should be put in emergencies and about training needs. These judgments are best made by the military services themselves (see Section III).

The second concern is that the military may be able to add little to the effectiveness of drug enforcement. That concern provides the primary focus of this study: What can be accomplished by increased military contributions to the interdiction effort?

The final concern is that a greater military role in drug interdiction may lead to corruption in operational units; the historical experience of agencies involved in drug enforcement has been that corruption control

[3]This statement is based on discussions with military officers involved in the interdiction program.

is a major problem. The issue of corruption potential is not addressed in this study.[4]

In February 1986, the Office of the Under Secretary of Defense for Policy requested that RAND undertake a study of the drug interdiction program. The study had seven major components:

1. A review of the extensive literature on the interdiction program. In connection with this review, RAND hosted a conference of officials and researchers to discuss possible approaches to evaluating the effectiveness of interdiction programs.
2. Collection and analysis of agency data on (a) the performance of various components of the interdiction system, (b) risks faced by participants in drug smuggling, and (c) prices at the export, import, and retail levels of the marijuana and cocaine markets.
3. Assessment of the costs and performance of various assets that can be used in interdiction efforts. A number of interviews were also conducted with individuals involved in coordinating the use of military assets in interdiction.
4. Development of an economic framework for analyzing the impact of increased interdiction effectiveness on the consumption of cocaine and marijuana in the United States.
5. Development of a simulation model to analyze the consequences of increased interdiction stringency at various points in the smuggling process, given probable adaptations by smugglers.
6. Development of an explicit theoretical model of the market for drug smuggling services, incorporating the effect of smugglers' costs falling with experience.
7. An analysis of the policy consequences of the research.

PRIOR STUDIES

A number of government-sponsored studies have examined various elements of the interdiction program. Table 1.1 lists those studies we have been able to review, in whole or in part. The table also briefly

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[4]There are characteristics of interdiction as an operational activity that make it less susceptible to systemic corruption than other forms of drug enforcement. Most important is the fact that interdiction involves the coordination of many units in a single activity, thereby reducing the discretion of the individual officer, which is the heart of corrupt enforcement.

Table 1.1

PRIOR STUDIES OF THE DRUG INTERDICTION PROGRAM

Research Agency	Sponsor	Year	Scope of Study
Center for Naval Analyses	Coast Guard	1979	Effectiveness of the Coast Guard Program
General Accounting Office	Congress	1983	Effectiveness of the current interdiction program
General Accounting Office	House Government Operations Committee	1985	Coordination of the interdiction program and the role of the National Narcotics Border Interdiction System
Systems Research Corporation	Customs Service	1985	Effectiveness of the Customs marine program
Systems Research Corporation	Coast Guard	1985	Ship procurement needs of the Coast Guard
Office of Technology Assessment	Senate Appropriations Committee	1986	Effectiveness of the current total interdiction program

describes the scope of each study.[5] None of the studies dealt explicitly with the potential contribution of the military to interdiction. They are primarily concerned with the potential impact of adding specific interdiction assets on quantities of drugs seized.

All the studies listed focused on the interdiction system. Little attention has been given to changes in smuggler behavior resulting from additional interdiction efforts—indeed, most studies assume that there is no adaptation at all. For example, the Systems Research Corporation (1985) modeled the impact of different configurations of surveillance and pursuit capacity at Customs interdiction stations along the East Coast, using historical data on smuggler behavior. The study assumed that smugglers would continue to use the same kind of equipment, import drugs in the same lot sizes, maintain their current evasive techniques, etc. To the extent that smugglers in fact do make adaptations to defeat changes in interdiction strategy and tactics, such modeling will overestimate the effectiveness of increases in interdiction resources. The models may work reasonably well in the short run, before smugglers can adapt; but in the long run, adaptation will decrease the effectiveness of the changes.

[5]There may be other studies whose existence was not disclosed to us. The nature of the topic requires that certain data must be closely held. In addition, some agencies are sensitive to the results of certain analyses, i.e., distribution of some studies has been limited because the sponsoring agency did not endorse the conclusions reached.

This is not meant as a criticism of the modeling efforts that have been undertaken. It is in fact very difficult to determine just what adaptations might be made by smugglers or to measure the consequences of such adaptations. But while the models may be useful for making comparisons among different equipment configurations, they are ill-suited for projecting the effects that adding particular assets will have on the availability of drugs.

The conclusions of the prior studies have many similarities, even though they do not all deal with the same aspects of the interdiction system. Most studies agree that the system is ineffective for the initial task of interdiction, i.e., detection. Many smugglers are simply not sighted. A 1985 Systems Research Corporation study of the Customs marine program concluded that "the weakest link in the southeast Florida environment is detection capability." The study estimated that detecting 50 percent of the smuggled vessels instead of the estimated 19 percent (in fiscal year 1985) would have raised the seizure rate from 5 percent to 13 percent. It would be very difficult to achieve similar increases through changes in later phases of the interdiction system without improvements in detection rates.

Similarly, a 1986 study of air interdiction prepared by the Office of Technology Assessment (OTA) concluded that "surveillance capability, more than any other single factor, determines the present interdiction rate." In a study performed for the Coast Guard in 1985, the Boeing Corporation estimated that there was little prospect for improvement in the interdiction system unless the percentage of targets sighted could be increased.[6] All the studies suggested that the system performs fairly well once a smuggler is detected, though the data supporting this proposition are rather weak.

Each study apparently assumes that the system is not subject to resource constraints at any point; i.e., increases in the number of sighted targets will not lead to declines in the percentage correctly sorted, pursued, and apprehended. This assumption would be violated if the sorting, pursuit, and apprehension capacity of the system were currently being exhausted; we suspect that for some modes and drugs, this assumption in fact does not hold.

These same studies also analyze operational aspects of the program. The U.S. General Accounting Office (GAO), in both its 1983 and 1985 studies, stressed the lack of coordination among the various interdiction agencies, a common theme in the many hearings on interdiction conducted by the House Government Operations Committee. Customs

[6]Information from a classified report by R. F. Poppe on ways to improve seaborne drug interdiction.

and Coast Guard communications systems often do not permit the passage of information between operating units of the two agencies (see, e.g., U.S. Congress, 1985, p. 283). The Systems Research Corporation found that, because of personnel and equipment problems, boats at a sample of Customs marine stations operated no more than 74 hours per month, on average. At some stations, the figure was less than 20 hours per month. Such low operating times, generally the consequence of inadequate numbers of trained personnel, obviously limit the performance of the system.

Each study noted the difficulty of assessing the prospects for expanded interdiction efforts. The OTA stated: "We simply do not have the data to support conclusions about how successful we are now, what impact our efforts have, or what the situation might otherwise be." Similarly, the U.S. GAO (1983) stated: "Evaluating the benefits of interdiction is difficult because of scanty information on overall interdiction results" (p. 53). Indeed, the GAO found significant errors even in the estimates of drugs seized.

All the prior studies are implicitly pessimistic about the possibility of greatly increasing the impact of the interdiction system. The OTA report makes clear that the scale of the task and the adaptability of smugglers give little reason for optimism. Earlier Center for Naval Analyses (CNA) studies estimated that almost an order-of-magnitude increase in Coast Guard expenditures on interdiction would be required to achieve any significant impact on marine drug smuggling. The Coast Guard later stated that it disagreed with this statement, although it provided no analytic support for its argument.

Most of the evaluations have been carried out in terms of seizure levels or seizure rates. All studies recognize the empirical limitations of these measures, since "threat assessments," the term used to describe projections of the flow of drugs into the United States (distributed over mode of transport and route of entry), are so uncertain. Some also recognize the conceptual limitations of seizure measures.

More surprisingly, the analyses pay little attention to arrests and incarcerations generated by interdiction, although these are potentially a highly significant product of interdiction efforts. There is also only an occasional reference to price (e.g., U.S. GAO, 1983, p. 16), which we believe to be the critical evaluation criterion. None of the studies make price the centerpiece of analysis.

RELATIONSHIP OF THIS STUDY TO PRIOR STUDIES

Given the emphasis of the earlier studies, it seemed appropriate to focus our attention on modeling the smuggling sector and on the rela-

tionship between interdiction and the consumption of drugs, rather than reanalyzing the operational aspects of the interdiction system. We have developed a simple economic framework in which interdiction raises the landed price of cocaine and marijuana and through that the price drug users must pay; this in turn will lower drug consumption. This framework is developed in Section II.

Adaptation and learning by smugglers is widely recognized to be a major impediment to improving the performance of the interdiction program, but it has not been formally incorporated in any of the analyses. We have attempted to incorporate such behavior into our work in two ways: First, we have developed a simulation model of the smuggling sector, emphasizing adaptation. In this model, different geographical routes and transportation modes present different risks and costs for smugglers. The impact of increasing the risks or costs associated with particular routes is analyzed in terms of changes in the total smuggling throughput, distribution across modes and routes, and smuggler costs. Data on actual risks, inasmuch as they can be estimated, are used. The impact of increased military involvement in the interdiction effort is captured by judgments about the effects of increased interdiction stringency on these risks and costs.

The simulation model incorporates both data and judgments about the major parameters of the interdiction system. The limitations of the available data prevented us from adopting our preferred approach, namely estimating a set of behavioral relationships and using these to project the effects of major increases in interdiction resources. We have attempted to make maximum use of the limited information that is available; however, for critical variables (e.g., seizure rates), we have used a range of values to determine whether the results are robust. The model is briefly described in Section VI, which also presents the results of simulations of the impact of increased interdiction stringency with the model. A more complete description is given in Crawford and Reuter (1988).

The second analysis emphasizes learning, as opposed to adaptation. We have developed an explicit theoretical model of the behavior of the smuggling market, which emphasizes the role of experience (i.e., learning) in determining a smuggler's risks and costs. The model assumes that more experienced smugglers have lower costs than novices, so increased seizures and arrests, imprisonments, etc., may do little to reduce the throughput capacity of the smuggling sector or to raise the import-level price. A summary of the model and its major results is presented in Section VII. A more complete description is given in Cave and Reuter (1988).

It was not possible to implement the second model empirically, because relevant data do not exist. Thus the simulations in Section VI use a fairly simple theoretical framework. They do not attempt to consider the subtleties of pricing behavior and structural change that are the focus of the theoretical model. We believe that the economic assumptions of the simulation model in general underestimate the robustness of the smuggling services market to increased interdiction. That is, if we incorporated the learning effects captured in the theoretical model, we would find that increased interdiction had less effect than is suggested in the simulation model. Since the major finding of the simulation work is that quite large increases in interdiction resources do little to increase the costs of smuggling, this is the preferred direction of bias.

Our modeling of the interdiction process (as opposed to the smuggling market) is fairly conventional. Interdiction—the seizure of drugs, personnel, and assets—is the result of a series of activities, including surveillance, identification, pursuit, and apprehension. Resources can be added to any of these activities, but the interdiction effects of such additional resources depend on the product of all of them.

Military resources are treated here simply as means for augmenting particular activities, thereby raising the probability of success in those activities. For example, tethered aerostats (balloon-mounted radars) along the U.S.-Mexico border raise the probability of sighting a smuggler crossing that border by air. The consequences of that increase for the probability of capturing the smuggler depend on the efficacy and availability of pursuit and apprehension resources, as well as smuggler adaptations.

The analysis of increased military involvement then revolves around a simulation model in which the added assets initially increase the probability of capture for particular smuggling modes and routes. Smugglers adapt to this increased probability in the model by altering their mix of modes and routes. We then determine what will happen to the total quantity of each drug entering the country by various modes and routes.

The study deals with only two drugs, cocaine and marijuana. We do not consider what the military might do with respect to the third major imported drug, heroin. Though significant amounts of heroin are seized at the border, these seizures come almost entirely from Customs inspections. Military resources do not seem to have much potential for affecting the risks of heroin importation, though the OTA (1986) suggests that new detection technologies similar to those used by the military in other settings might improve Customs inspection performance.

STRUCTURE OF THE REPORT

Section II presents our study's analytic framework, using economic concepts to relate interdiction to drug consumption. From this we develop our basic criterion for judging effectiveness of interdiction, namely, the price difference between import- and export-level transactions. Section III provides a description of drug smuggling methods, along with historic data on the performance of the interdiction system. Section IV describes the military contributions to interdiction and the process by which these contributions are provided. The final descriptive section, Section V, analyzes the recent performance of the interdiction system.

The next three sections are analytic. Section VI presents the results of a simulation model which attempts to capture the impact of additional military resources on the cost of imported cocaine and marijuana, taking into account adaptation by smugglers to changes in the level and distribution of interdiction resources. Section VII summarizes a related theoretical analysis which rigorously models how interdiction may affect the structure and performance of the market for drug smuggling services. In particular, this model traces the dynamic consequences of smugglers' "learning by doing," a notion distinct from adaptation to changes in interdictors' tactics. Though not yet empirically implementable, this model does help explain certain aspects of the recent performance of the smuggling market.

Finally, Section VIII builds on the description and analysis to address the policy question that initiated the study: What are the consequences of increased military involvement in the interdiction program?

The report also includes three appendixes. Appendix A analyzes the consequences of increased interdiction on the price and quantity of drugs in the source countries. Appendix B presents and analyzes drug price data made available by the Drug Enforcement Administration (DEA); the analysis suggests that there is indeed a relatively well-determined market price for cocaine and that this price has some predictable features. Appendix C presents a simple diagrammatic analysis of the relationship between drug interdiction and drug consumption.

II. AN ANALYTIC FRAMEWORK

We assume that the reduction of cocaine and marijuana use is the primary, though not the sole, goal of the interdiction program. In this section, we describe a framework for analyzing the effects of interdiction on the use of these drugs in the United States and present a criterion for high-level policy evaluation of the overall interdiction program.

There are three ways in which interdiction might be expected to reduce the consumption of drugs in the United States. First, the quantity of drugs entering this country might be physically limited so that, say, no more than 25,000 kilograms of cocaine could be smuggled. Consumption would be limited to this amount, and price would adjust correspondingly. This is a sufficiently implausible situation that we give it little consideration.

Interdiction can raise costs for smugglers, but given the conditions of production in the source countries[1] and the availability of smuggling resources, there will always be some price at which it is worth shipping enough of a drug to satisfy the demand in this country. That is, the system's throughput is determined by demand/supply conditions, with interdiction affecting consumption only by raising the costs, and possibly altering the conditions, of distribution.

The second effect of interdiction might be to make the availability of drugs less predictable, thus deterring drug users from habitual or frequent use. This effect can be best understood through a rather artificial example: Assume that there are only a small number of marijuana users in some isolated town. They are serviced by one retailer and have no other way of obtaining the drug.[2] He will sell them only one ounce at a time. Their wholesaler, after years of faithful service, takes up heroin use and becomes unreliable. As a result, there is now a one in three chance that marijuana will not be available when they seek it. This makes marijuana consumption less attractive than other recreational habits, so some users drop out. In addition, those who continue to use it are less generous and initiate fewer new users. Even though

[1]A major puzzle in the analysis of cocaine and marijuana markets is the chronic excess supply in the source countries, at least as estimated by the Department of State and other agencies. It appears that even dramatic cut-backs in production would leave more than enough marijuana and cocaine available to supply the current amounts consumed in the United States without significantly increasing retail prices.

[2]That is, it would be very expensive and risky for any user in this town to go to another city and find a connection.

the price of marijuana may not have risen, usage (both incidence and prevalence) may decline.

The critical element of this tale is that the market is small and inventory flexibility is limited. For the national market in cocaine and marijuana, neither condition is very plausible. There seem to be many importers, and both users and wholesalers may hold considerable inventories.[3] Faced with increased uncertainty, both populations might respond by increasing inventories. This would raise the costs of sellers and users (since they must tie up more money in inventory holdings), but given the cost of capital relative to other costs, an additional month's inventory can have a significant effect only if it adds substantially to the probability of being robbed.

Some individual importers do not operate in a national market but sell to wholesalers in only one or two cities. If those wholesalers do not have connections with other importers, the loss of a single large shipment might lead to temporary shortages in the metropolitan areas they service. But discussions with a few high-level dealers and importers suggests that there is a great deal of selling across metropolitan markets. For example, a San Francisco cocaine importer had regular customers as far away as Pittsburgh. In the absence of information to the contrary, we shall assume that there is a national market at the import level.

Finally, interdiction might raise the price of drugs and thereby decrease the quantity consumed. This is the effect on which we shall concentrate.

Interdiction increases the risks and costs incurred by participants in the drug trades. In a mass market, these risks and costs determine how much of each drug is available at a given retail price. Interdiction differs from other enforcement efforts only in the particular component of the distribution system that it targets; analytically it can be treated like other enforcement programs.

More stringent interdiction raises the price smugglers charge for their services. This leads to increases in the landed or import price of drugs, which raises prices further along the distribution system and eventually increases retail prices. That, in turn, reduces consumption, at least in the long run.

This section examines the components of this argument. We first examine the relationships between risks and prices at a particular level of the distribution system and then among prices at different levels of

[3]Marijuana and cocaine users typically buy quantities large enough for 10 or more consumption sessions; marijuana users probably buy enough for 30 sessions. This economizes on transaction costs. Heroin users, because of their poverty and lack of self-control, rarely buy more than one day's consumption at a single transaction.

that system. We next show how the primary effect of interdiction is captured in the difference between the import and export prices of a drug. After a brief examination of the limited evidence available on the impact of price changes on the consumption of illicit drugs, we deal with a number of related issues including (1) the evidence that price is a meaningful measure in illicit drug markets, (2) the effect of interdiction on export prices, and (3) the weaknesses of alternative nonprice criteria for evaluating interdiction effectiveness. We conclude by summarizing the arguments of the section and relating them to the other sections of the report. In general, this section focuses on basic behavioral issues, leaving details of modeling to Sections VI and VII.

RISKS AND PRICES: AN ECONOMIC ANALYSIS OF DRUG ENFORCEMENT

Drugs are sold in noncoercive transactions in which the parties must agree on a price. The seller's motivation, certainly at the higher levels of the drug trades, is simply pecuniary. He seeks to maximize his welfare, which is a function of his income from the trade and his estimate of the risks associated with his activities.

The dealer may forgo income in order to lower his risks. For example, he may accept a lower price from a regular customer rather than incur the risks associated with looking around for customers (wholesalers) who might be willing to pay more. Searching for new customers is dangerous because it may bring the seller into contact with an informant or an undercover drug enforcement agent. However, there is some differential, between the price offered by a regular customer and the price the seller believes is available on the open market, at which the seller will enter the open market rather than complete the sale to that regular customer.

Subject to that risk factor, the seller wishes to maximize the unit price, just as the buyer wishes to minimize the amount he pays for the drugs. The buyer wants to reduce search time because he also incurs risks in a world in which enforcement authorities may pose as sellers as well as buyers. The price at which buyer and seller transact is affected by their perceptions of the price that would obtain if they transacted with other participants.

What determines the "price" that prevails at a particular level of a market? We are dealing here with mass markets, in which many thousands of dealers operate. Assuming competition (discussed in Section VII), the price is determined largely by costs, rather than by idiosyncratic characteristics of individual buyers and sellers. But the

term *price* is itself a simplification; there are many prices. We now turn to the relationships among these prices.

Cocaine and marijuana are sold through long distribution chains. Cocaine is imported in bundles frequently as large as 250 kilograms and sold in units that may be as small as 1 gram; marijuana enters in multi-ton shipments and is sold in units of ounces. Since each participant in the distribution system wants to reveal his participation to only a small number of others, the result is generally a lengthy series of independent sales transactions.[4] There may be as many as five links between the importer of cocaine or marijuana and the final buyer of the drug.[5]

Each level of distribution can be viewed as a separate market, although these markets are clearly related. Those who wish to purchase one ounce of cocaine for retail distribution operate in a different market from those who buy 5-kilogram bundles to sell to wholesalers. However, the retailer's costs are affected by those of the wholesaler.

The identification of separate markets for different levels of the distribution system provides a means of linking changes in import prices with changes in retail prices. The wholesaler who buys from importers (in 50-kilogram bundles, say) must pay a higher price as a result of interdiction. When he sells to the next-level dealer (perhaps in 5-kilogram bundles), he will pass on that increase in cost and add to it, as he would even without the more stringent interdiction, the costs associated with his own distribution activity and his own profit margin.

Appendix C presents the basic analysis of the relationships between stages of the market, including a graphic presentation of the way interdiction, in a simple two-stage distribution system, affects the retail supply curve.

Costs in all stages of drug distribution (at least between in-country production and U.S. retailing) are dominated by risks, both direct and indirect (see Reuter and Kleiman, 1986). Direct risk refers to the probability of the dealer, his agent, assets, or drugs being seized by enforcement agencies. Indirect risk refers to the adverse consequences, mostly related to violence, that arise from the actions of others as a

[4]There are some integrated distribution organizations that use agents to sell through a number of levels of the market. This does not appear to be the dominant mode, however; normally, each transaction involves an arms-length sale, though the seller may provide credit to the buyer.

[5]If each successive dealer is willing to transact with ten customers (lower-level dealers), then it takes four sales to break down a 250-kilogram bundle into the 25-gram units bought by the retailer. Clearly, this is only an approximation. Higher-level dealers will generally be willing to deal with fewer than ten customers; lower-level dealers may accept more than ten. But there are likely to be at least three or four transactions between professional importer and retailer.

result of law enforcement. The dealer must be concerned with threats of theft (of drugs, money, or other assets) by others, and these threats are determined in large part by the value of the drugs; this value, in turn, is greatly influenced by the intensity of law enforcement.

Non-risk costs are the costs of equipment, such as boats for the importation of marijuana or radio equipment to monitor the progress of shipments. The available data strongly suggest that such costs are quite modest for mature smuggling organizations. Though some smugglers do purchase relatively expensive and elaborate counterdetection equipment, its cost, even if defrayed only over a small number of trips, is a small fraction of the revenues generated by sale of the shipment. For example, a 5-metric-ton marine shipment of marijuana, if sold at $500 per kilogram, yields total revenues of $2.5 million. A great deal of equipment can be bought for 10 percent of this sum.

Apart from equipment, all smuggler costs are risk-dominated. For example, the high payment to pilots for flying drug shipments is compensation for incurring (1) the risks of being captured and receiving long prison sentences and (2) the risks of physical harm, if not death, from flying under very adverse conditions (e.g., night flights in mountainous areas, at low altitudes, to remote and ill-equipped airstrips). These risks are themselves an effort to lower the probability of capture.

In effect, interdiction is a tax on smuggling. The tax is levied in kind, i.e., the government seizes goods and persons rather than money,[6] and the tax rate is not known with certainty by the smugglers. Nonetheless, we can use the techniques of tax analysis to examine the impact of increases in the stringency of interdiction.

As interdiction becomes more effective, the direct risks rise. Smugglers' agents (pilots, loaders, sailors, etc.) all face higher probabilities of capture. Whether smugglers themselves face increased risk depends on their strategies and those of the interdiction agencies. If smugglers never associate themselves with the drugs, and interdiction agencies do not offer arrested agents credible bargains in return for leading the agencies to the smugglers, then the smugglers' own risks are relatively insensitive to the interdiction program.[7]

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[6]Money has occasionally been seized from smugglers, following extensive undercover investigations. Though recently increasing, the totals seized are small in comparison with the costs imposed on smugglers through incarceration or drug seizures; in 1986, the total financial assets seized through interdiction amounted to $121 million (National Drug Enforcement Policy Board, 1987, p. 79).

[7]Absent an effective extradition treaty with the source country (as is currently in effect with Colombia), smugglers who do not leave the exporting country face no risk of capture by U.S. interdiction forces.

Increased risks to agents will lead these agents to demand a higher price for performing their tasks.[8] That in turn will increase the smugglers' costs, so that, even if there is no change in their own risks, they will seek a higher price in order to continue to supply their customers (importer/wholesalers). Since, as a first approximation, all of the smugglers incur these higher costs, they will not lose market share (even though the total market will shrink) as a result of raising their price.

The "price" here refers to the difference between the price at which the smuggler purchased the drug in the exporting country and the price at which he sells it in the United States. This markup is an "efficient" statistic; it should capture, under the assumption of competition,[9] all the information about distribution costs. Certainly, changes in the costs of smuggling should be captured by changes in this price difference.

There are two caveats about the use of this markup as the measure of interdiction effects. First, interdiction may also affect export prices. Thus looking only at the import-export price difference may underestimate the effectiveness of interdiction, since an increase in the export price can also raise the retail price of drugs. It turns out, as discussed later in this section (and in more detail in Appendix A), that the effect of interdiction on export price is likely to be slight. Moreover, at least for marijuana, export price is only a small fraction of import prices, so that even quite large proportionate changes in export price would have little effect.

Second, it is possible that some effects of interdiction on users and domestic dealers are not captured in the induced increases in import prices. For example, a shift to domestic marijuana might generate less uncertainty in downstream supplies than would a high seizure rate. The domestic supply system is more decentralized and thus less prone to seizure-induced disruptions. Since our ultimate interest is the impact of interdiction on drug consumption, we would like to have a measure that captures this post-importation effect.

Again, however, we suggest that this is likely to be a slight effect compared with the change in the import-export price difference. The market for marijuana is simply too dense now for changes in the

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[8]Not all agents performing a given function face the same risks; for example, pilots differ in their experience. But increased interdiction severity will certainly not decrease the risk for any set of agents. Section VII explores in some detail the consequences of heterogeneous risks.

[9]Even if the smuggling market is not perfectively competitive, cost increases arising from interdiction will result in higher prices. However, the baseline difference, where there is *no* interdiction, will include monopoly profits as well as risk compensation and other factors.

frequency of seizures to have much effect on the regularity of supplies to individual customers.

Later in this section, we shall discuss a number of other post-import effects that may not be captured by the import-export margin. We believe that the available evidence suggests that these are at most second-order effects. Therefore, we shall focus on the interdiction-induced increment in the import-export margin.

To summarize, the impact of interdiction on the drug market can be captured by changes in the difference between import and export prices. For smugglers, those prices are dominated by interdiction-related risks. We now turn briefly to consideration of the component costs of smuggling and the impact of adaptation by smugglers, since adaptation is part of the behavioral response that determines how interdiction changes affect the smuggling sector.

SMUGGLER COSTS AND ADAPTATION

There are three component costs of drug smuggling: drugs purchased in the source country, transportation (equipment and operating costs), and personnel. Smugglers—as a group, if not individually—have a variety of means available for bringing drugs into the United States; these means, reviewed in Section III, differ in the composition of their costs. Interdiction programs can affect the price of any of the three input factors and hence smugglers' preferences among different modes of importation.

For example, the optimal adaptation to increased interdiction might be to alter the distribution of shipments among modes of transportation. As the probability of intercepting small planes increases, the risk compensation payment for pilots rises. This might shift more cocaine smuggling away from general aviation to commercial planes (where it can be hidden in cargo); smuggling in commercial planes probably has a lower personnel cost per unit smuggled, but it may entail a larger risk of loss of drugs.

The differences in the components of smuggling costs are best illustrated by a comparison of heroin and cocaine importation. Heroin importation rarely involves dedicated transport; heroin is smuggled in general commercial cargo, except for heroin of Mexican origin. The courier's risk of capture is probably also fairly low, but the severe sentences received by heroin smugglers, as well as their exposure to violence from other participants, may make the expected penalty relatively high.

Heroin importing is thus a high-cost mode of smuggling because only fairly small bundles (usually 1 to 5 kilograms) are brought in. In contrast, cocaine typically arrives in bundles of 10 to 500 kilograms; shipments of more than 1,000 kilograms are not unheard of. Air smuggling of cocaine in large bundles probably involves high transportation costs and, on a per-kilogram basis, fairly modest personnel costs.[10] The materials loss rate (in the past two years, at least) for cocaine is high, compared with heroin.

The increment to the import-export price differential arising from interdiction cannot, however, be measured simply by the direct costs imposed on smugglers, even when the prison sentences and the lost equipment that go along with drug seizures are included. These direct costs do not take into account the costs of evasion by the smuggler himself or his increased uncertainty, as opposed to the increased compensation he must pay agents for incurring the risk of legal sanction, which is captured in their wage rates.

In the absence of any interdiction at all, i.e., in a world in which smugglers could send drugs by mail or parcel post, the transportation cost per kilogram would be a few dollars. However, transportation is not the only relevant cost, since the goods change hands and a margin must be allowed for each sale transaction. The difference between the export price and import price of any good is more than pure transportation costs. The differential in all market transactions must include some allowance for various kinds of risk-taking.

Without interdiction, but with a continued prohibition on the sale of drugs, smugglers would still incur risks at the point of first domestic sale or first sale to a domestic agent. That suggests that the difference between the import-export margin and pure transportation costs is only a first approximation to interdiction effectiveness; allowance must also be made for the entrepreneurial risks of importing. Since we will be looking at the impact of changes in interdiction stringency, the base cost (i.e., the cost in a world without interdiction) need not be precisely specified.

Factors other than interdiction also influence the export-import markup. Threats from other participants, another significant source of risk, may in themselves be an indirect product of interdiction, inasmuch as interdiction raises the value of the drug at the point of import and hence the incentive for stealing it. But the export price of a drug (at least in the case of cocaine) may be high enough that the threat would exist even in the absence of interdiction efforts. As

[10]If a pilot is paid $250,000 for a flight with 250 kilograms, a fairly typical load as revealed by seizure data, the per-kilogram cost for his services is only $1,000; this is about 5 percent of the markup from export to import.

already mentioned, this may be a major factor in explaining the extraordinarily high markup (perhaps $100,000 per kilogram) in heroin importing. A very small share of all heroin imports are seized, and although convicted heroin couriers receive harsh penalties, it seems unlikely that risk of prison accounts for most of the rest of the markup, since few couriers are caught.[11]

In this connection, it is useful to think about the factors that influence the effectiveness of interdiction expenditures. The limits of interdiction effectiveness are probably determined by technological and geographic factors. Interdiction of Mexican heroin appears to be very weak because the U.S.-Mexico border can be crossed at many points (there is little channeling at point of exit or entry), and a high-value crossing can be accomplished very suddenly by a single individual in a large crowd of similar individuals (i.e., a low-profile target). Consequently, Mexican heroin can be smuggled at a low unit cost.[12] Intensified interdiction may be able to do little to raise that cost.

At the other extreme, interdiction of Thai marijuana is probably quite effective because there is only modest commercial traffic, in which potential targets can hide, between the United States and Thailand. The distance to the United States is great (rendering private marine or air traffic unavailable), and there are large fixed costs to the smuggling venture because of the relatively low value-to-volume ratio. It does not take much investment in interdiction to raise the importation cost of Thai marijuana, as compared with the no-interdiction situation.

Adaptation is a response to changes in interdiction strategies and tactics. It can reduce the effectiveness of increased interdiction efforts, but it cannot entirely neutralize them. That can be done through the related but distinguishable phenomenon of "learning," examined in Section VII. Smugglers may become more efficient as they acquire experience. Thus we may observe no increase in interdiction effectiveness some time after interdiction resources have been augmented, because the population of smugglers has become more experienced in

[11]It is worth mentioning here another analytic problem, determination of the correct base for calculating interdiction effectiveness. Should we use a weight or dosage unit base? The import cost per dosage unit for heroin may in fact not be much higher than for cocaine, because dosage units are so much smaller, approximately 20 milligrams pure for heroin versus approximately 300 milligrams pure for cocaine. But the dosage unit is endogenous to the enforcement system; heroin doses are smaller at least in part because the price per unit weight is higher. Changes in interdiction effectiveness can thus affect the dosage unit. Since our concern is with the effects on a single drug, rather than cross-drug comparisons, we shall use the more convenient and measurable metric, weight.

[12]The low cost of smuggling Mexican heroin compensates for its relatively high production costs. Heroin is much cheaper in other source countries, but importers from those countries face much higher smuggling costs.

the intervening period. Without such learning, even adaptation cannot prevent some positive feedback from increased interdiction.

Increases in import prices should feed through to retail prices. An increase of $1 per unit in the markup from export to import will, however, generally raise the price at retail level by more than $1. All the participants in the system after importation incur higher inventory costs, since they must pay more for the drugs that they need to hold for sale.

Inventory costs depend on (1) the rate of interest dealers impute to their investment and (2) the length of time they hold the drugs.[13] There is no published information about either of these parameters. An earlier RAND analysis (Polich et al., 1984) attributed high values to both of them, simply for the purpose of establishing a reasonable upper bound on the price effect of interdiction. If we assign a cost of capital of 100 percent per annum and assume that it takes three months for the drug to move from import to final sale, the inventory cost will add 25 cents to each initial $1 increase in the import price.

This does not exhaust the possible post-import effects of increased import prices. A major source of risk, and cost, to participants in the drug trades is threats from others in the same trade. Cocaine wholesalers face threats from their customers, who may try to steal drugs, and from their suppliers, who may either sell them drugs of lower than stated quality or simply steal their money. The higher the price of the drugs, the greater the temptation to steal or defraud.

It is not likely that import price increases will have proportionate effects on these risks, because the risks will have been neutralized by dealers adopting precautions in their transactions with others. Such precautions may be adequate to deal with the greater threats arising from the increased incentives for theft, etc., but if dealers are unable to take further precautions, they may require still higher compensation for the personal risks that they face as a result of the higher value of their inventories. To take account of this, we allow a $1 increase in import price to produce a $2 increase in retail price.

We now move to consideration of the second component of the analysis, the effect of prices on consumption.

DRUG CONSUMPTION AND DRUG ENFORCEMENT

No models have been developed that relate drug consumption to drug enforcement, or indeed to any other aspect of drug policy. We

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[13]Seizures of drugs also affect inventory costs. However, post-importation seizure rates are likely to be small, if only because holdings are dispersed rapidly after import.

assume that the more expensive and difficult a particular drug is to obtain, the less of that drug will be consumed. It is a plausible assumption, but one for which we have a dismaying lack of evidence, since the existing measures of drug consumption and prices (and other availability indicators) are too crude to permit testing. Nonetheless, the body of economic support for a relationship between price and consumption is too strong to allow much doubt that, at least in the long run, higher price will lead to lower consumption.

This is, of course, by no means a complete explanation of drug consumption. We simply do not know what determines variation in the consumption of illicit drugs in the population. For example, the percentage of high-school seniors reporting heavy use of marijuana has declined dramatically since 1978 (Johnston et al., 1986), following a five-year period in which that same rate doubled. No authoritative explanation has been developed for either the pre-1978 rise or the subsequent decline, though the attitudinal data collected in the same survey suggest that changes in the public view of the health consequences of marijuana use may be an important factor. Similarly, there are also unexplained variations in drug use across metropolitan areas within regions of the nation. Washington, D.C., data show widespread use of phencyclidine (PCP),[14] a drug that seems to be very little used in most other Northeastern cities. No explanation has been offered for this variation. Once a particular drug has become widely used in a population, however, it is likely to continue to be used heavily for some time; abrupt declines of such use seem to be rare.

We make no claim to have developed a model capable of explaining such variations in drug use patterns. Changes in social structure and general behavior are known to affect drug use, but these are likely to be relatively long-run factors, changing over periods of years rather than months or weeks; moreover, they are seldom amenable to public policy. Our analysis would be enriched by a general theory of drug use, but it does not absolutely require one. We deal with a shorter time period, in which these attitudinal and structural factors may be assumed to be fairly constant.

DRUG CONSUMPTION AND PRICE

The negative relation between price and demand is one of the better-established propositions in economics. However, there are argu-

[14]Urinalysis of arrestees in the District of Columbia indicated that about 30 percent had consumed PCP within the previous 30 days (Carver, 1986). In contrast, 1986 data for New York City showed only 4 percent of arrestees having recently consumed PCP. High-school senior survey data also show remarkably high use rates for PCP in the Washington area.

ments that it may not hold for addictive drugs such as heroin and the newer modes of cocaine. It used to be believed that demand for these drugs was unresponsive to price; an addict purchased the amount of drug that he required for each day, and if the price of the drug rose, he sought the additional money (presumably through crime) to maintain his purchase level. A growing body of empirical research suggests that this is not a good description of the behavior of heroin users, the group about which most is known.[15]

Heroin users, in the face of an extraordinarily expensive and dilute drug, spend almost their entire income—and engage in very risky behaviors—to obtain the minimum required to maintain their addiction. A higher price will lead some of them to enter treatment programs, some to try to reduce their usage to less than daily consumption, and others to increase their criminal activity. But overall it is highly probable—the data do not permit any stronger statement—that the quantity consumed declines with increasing price. Indeed, it is even possible that the decline is quite substantial, i.e., that demand is elastic with respect to price, so that a 1 percent increase in the price of heroin will lead to more than a 1 percent decline in the consumption of the drug.

This does not prove that demand for all drugs is price sensitive. In at least some respects, this relationship is idiosyncratic to heroin. For example, cocaine users are much less economically deprived than are heroin users.

We believe that higher price will reduce demand, even for cocaine. Though some current heavy users may be unaffected by price increases, such increases will slow the flow of occasional users into the pool of heavy users. Aggregate consumption will then decline, as will the number of heavy users.

For our analysis, it would be desirable to have estimates of the price elasticity of demand (i.e., the percentage by which demand will fall following a 1 percent increase in price) for each drug. This would enable us to relate a given increase in the interdiction rate, through price increases, to reductions in total consumption. However, no data-based estimates of price elasticity of demand exist for either marijuana or cocaine.

The usual method for estimating the price elasticity of demand for a good is to analyze the variation in demand as a function of price and other variables. Unfortunately, the existing data on drug prices and consumption, either over time or across areas, are too weak to permit such an analysis. We must instead rely on indirect and inexact approaches.

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[15]For a summary of recent research on this issue, see Wish and Johnson (1986).

Two factors are likely to affect an individual's elasticity of demand with respect to a particular good: the current share of his total expenditures going to that good and the availability of substitutes at comparable prices. The higher the share of the good in an individual's total expenditures, the more a percentage increase in the good's price will lower his expenditures (*ceteris paribus*). The second factor is less easily expressed, but we may assert roughly that the greater the difference between the current price of a good and that of any acceptable substitute, the less sensitive demand for that good is to price. For example, the demand for claret is very sensitive to price, since, for most consumers, burgundy is a close substitute. The demand for skiing may be very inelastic simply because there are no comparable sources of winter thrills.

We may be able to make a reasonable guess about the elasticity of demand for cocaine and marijuana by considering these two factors. The arguments are clearer for marijuana than for cocaine.

At its current price, marijuana is probably a great deal cheaper than any alternative means of obtaining a comparable effect. A "joint" that will provide a euphoric effect for about 2 hours costs only about $1.[16] For most users, marijuana expenditures constitute a modest share even of discretionary expenditures. This suggests that marijuana consumption may be quite inelastic with respect to price.

There is, however, an important class of user—adolescents consuming more than one joint a day—for whom marijuana may be a large share of total discretionary (or even nondiscretionary) expenditures. They are an important group to consider, because they may account for a significant share of total marijuana expenditures. Their consumption of marijuana will be more sensitive to increases in price, precisely because its cost is such a large share of their total budget. Unitary elasticity (which implies that total expenditures on marijuana remain constant as the price changes) is the most likely result for this group; alternative sources of the same kind of "high" are not readily available to them.[17]

Most marijuana users, even those who use it heavily for some period, are not addicted; however, most heavy users eventually shift from marijuana to other drugs. The population of cocaine users, on the

[16]The high-school senior survey data indicate that in the 1980s, a joint contained about 0.4 gram of marijuana. At a price of $75 per ounce (28 grams), this yields a price of approximately $1. For more details, see Reuter (1984).

[17]It should be noted, however, that heavy marijuana users among the high-school senior population are frequently multiple drug users. Increases in the price of marijuana may lead them to shift more of their expenditures to the other drugs they are currently consuming anyway.

other hand, apparently now includes a significant portion of addicted users. Their demand may be very inelastic.[18]

Total consumption of cocaine, particularly given the newer modes of administration, such as freebasing, is probably dominated by a relatively small number of heavy users. This would suggest that the short-run elasticity of aggregate demand is small, reflecting the response of this group. However, the long-run elasticity of demand may be much greater, as the flow of occasional users into the heavy user pool is reduced by the cost of acquiring the habit.

It is difficult to go beyond these general statements, which only suggest that the quantities consumed of both cocaine and marijuana are likely to decrease less than proportionately to price increases. We have been unable to obtain any data on this subject, but we believe that total demand for both drugs is quite inelastic. In our simulations, to ensure the impact of interdiction is not minimized, we use relatively high estimates of the price elasticity of demand for each drug.

The price that we are referring to here is the retail price of the drug, which is in fact a complex of prices, varying by location and quantity. Heavy users of cocaine are likely to buy in ounce units at a lower per-unit price than that paid by lighter users, who buy in 1-gram units. The price is probably lower in large cities, particularly in those close to the major importation points, than in smaller cities. But the relationship among these different prices may be fairly stable, so we can refer to a single retail price index at any one time.

PRICE UNIFORMITY

One objection to the use of price in determining interdiction efficacy is that prices are not uniform at a given point in the market. If there is very large variation in the price for, say, a 5-kilogram cocaine lot in Miami in the third quarter of 1986, then (1) the market mechanism would appear to work poorly, raising questions about whether price is indeed a measure of relevant risks, and (2) the measurement of price trends is more difficult simply because more observations are needed to attain a given level of accuracy.

To make a judgment about this, we obtained data from the DEA on the wholesale price of marijuana and cocaine. These data, discussed in more detail in Appendix B, consist of all records of negotiations or buys involving more than 1 kilogram of cocaine or 100 kilograms of

[18]As in the case of heavy marijuana users, there is growing evidence of multiple drug use by heavy cocaine users, which suggests that they may shift their mix of drugs in response to a rise in the price of any one of them.

marijuana in each quarter, from the first quarter of 1985 to the third quarter of 1986.

There is, of course, some question about whether data gathered by an enforcement agency in the course of its investigations represent prices in actual transactions. We offer three reasons for accepting these data as representative of markets: First, a number of them are based on observations of consummated transactions, presumably often involving informants. These are genuine market transactions, and we assume that they are recorded accurately.

Second, there is very little difference between "buy" data and "negotiate" data, i.e., data on deals where no actual transaction occurred. This is explained by the third reason: Agents need to bargain hard in negotiations precisely in order to establish their bona fides. The undercover-agent seller does not want to seem too eager to engage the buyer in a transaction by offering too low a price. On the other hand, he wants to get a transaction, so he will try not to set the price too high. Indeed, the very reason for maintaining the database that was provided to us was to give agents accurate figures about prevailing prices when they enter into undercover transactions.

Even before any adjustments are made for differences in quantities sold or transaction locations, the narrowness of the range of reported prices is striking. For example, in the fourth quarter of 1985, the highest price reported for a kilogram of cocaine was $37,000, and the lowest price was $25,000. While this is an enormous range in comparison with, for example, the price paid for another semirefined agricultural product, flour, at any one point in time, it looks more modest when compared with the range of flour prices over an entire quarter.[19]

When geographic variation is taken into account, these data suggest that one can indeed talk about "the" price of 1 kilogram of cocaine, at least in the major markets. To illustrate, we divided the nation into three regions: Florida, metropolitan New York, and the rest of the nation. Precisely as one would expect, the median price reported for Florida, the state with by far the largest number of observations, is significantly lower than that for the rest of the nation: $34,000 versus $40,000 in fourth quarter 1985.

Moreover, the range of regional prices is more limited than in the total dataset. For example the range for Florida between the 25th percentile and the 75th percentile (a standard nonparametric measure of variation in a series of observations) is only $7,000 in the second quarter of 1986, compared with a median price of $28,000. In the same

[19]If there are fluctuations in the average price during the quarter, a sample of daily prices will show a greater range than exists on any single day.

quarter, the interquartile range for all the observations outside of Florida (apart from metropolitan New York) is $10,000, compared with a median price of $36,000. Given that the regions outside of Florida may constitute different markets and are generally further from the point of importation, we would expect both a higher median and more variation, just as we found.

Moreover, when we separate out the larger transactions, those involving 10 to 100 kilograms, the prices are lower than for those of less than 10 kilograms. This is consistent with the hypothesis that the data constitute samples from different levels of the market and that larger lots sell at lower unit prices because fewer risks have yet been incurred. The median price for the third quarter of 1986 for sales of 10 to 100 kilograms was $27,000, compared with $34,500 for sales of 1 to 10 kilograms. We would expect most of the sales by smugglers to be of more than 10 kilograms. Thus our use of the average price from all transactions larger than 1 kilogram as a surrogate for the import price will exaggerate the effectiveness of interdiction efforts.

We restricted our analysis to the cocaine price data, because too little marijuana data were available for specific quarters, regions, and transaction sizes to support a detailed analysis. But the price range within the very disparate set of transactions recorded by the DEA was still fairly modest: For the first quarter of 1985, the interquartile range (per pound) was $150, compared with a median of $375.

We believe these analyses support our contention that price is a meaningful term in analyses of drug market behavior. With that we now turn to consideration of how interdiction affects export prices.

INTERDICTION AND EXPORT PRICES

While we are not ultimately much concerned with export prices, since they have only slight impact on U.S. consumption,[20] they play a role in the analysis because our evaluation criterion involves the export-import price differential. They are also important for purposes of international relations, since earnings to source country nationals may be a significant economic factor for some of these countries.

As it turns out, the direction and extent to which increased interdiction affects export price may depend on characteristics of the interdiction program. We illustrate this by considering two simple models,

[20]The export price for cocaine is no more than 5 percent of the retail price in the United States. For marijuana, export prices are less than 1 percent of domestic retail price. Major changes in these prices are not likely to have much effect on U.S. consumption.

both of which involve some rather artificial assumptions, but do capture important variations among different drug markets. A more formal analysis is given in Appendix A.

Seizure Model I: No Adaptation Possible. In the first model, we assume there is only one means for shipping cocaine to the United States and that all the cocaine is grown in Colombia. Smugglers cannot adapt to increased effectiveness in interdiction; they must simply accept a higher probability of seizure and the attendant costs.

In real life, the current landed price of cocaine is only 10 percent of the retail price. From that we may deduce that the short-term elasticity of demand for cocaine with respect to the import level price is very low. If we assume that the elasticity of demand with respect to retail price is high, say −3, then, as a first approximation, the elasticity with respect to import price is only about −0.3. Consequently, we shall assume that increases in import prices arising from better interdiction have little effect on final demand.

The effect of raising the interdiction rate, then, is to increase total demand at the export level. That demand (shipments) has two components: seizures and consumption. Increases in the seizure rate have little effect on consumption, since import prices are such a small percentage of final price, and any consumption reduction will be overwhelmed by the increased export demand to replace seizures. Export prices will rise, as will total source-countries export earnings from cocaine.

We assume, here and in the rest of the analysis, that the supply curve for drug exports is upward-sloping in both the short and the long run. However, increased interdiction has some potentially perverse long-run consequences in this model. Assume that capital investments in the cocaine production sector are quite long-lived. This is, in fact, a reasonable assumption, given that coca plants take three years to reach maturity, although they can produce some coca within a few months. Now assume that the interdiction rate, after rising, declines to its earlier level. The long-run supply curve of cocaine for export will have shifted out (since there are now more plants coming to their high-yield period), so that at the old interdiction rate, the export price will be lower than it was before. Thus, we may observe increased exports, as compared with the earlier situation, even though the seizure rate has fallen to the old level.

Seizure Model II: Interdiction Lowers Export Prices. In the second model, the response to increased interdiction effectiveness is the use of more expensive routes; seizure rates are unchanged. Total export demand will certainly decline. Final demand will decline because of higher prices, and total seizures will fall, since the seizure

rate is no higher than before and total consumption has declined. The result is falling prices to producers.

This model may well be applicable to the Mexican heroin market. By forcing smugglers to use relatively expensive land couriers, the border interdiction effort raises import prices with few significant seizures.

We should note that neither of these models includes a domestic U.S. production sector. If increasing import prices induces higher domestic production, then total export earnings may be reduced, even when smugglers cannot make any adaptation to lower the seizure rate. This may be precisely the explanation for the decline in marijuana export prices in the face of increasing interdiction stringency.

SHORT-TERM ADAPTATIONS IN THE EXPORT SECTOR

The above analyses deal with long-run adjustments. There are some differences in response to short-lived intensifications of enforcement, such as the operations named Hat Trick I and Hat Trick II. These were efforts to create a blockade off Colombia and in the Caribbean, with substantial Navy involvement, immediately after the fall harvest of marijuana. To determine what we can learn from responses to such intensifications, we must consider possible short-run adaptations.

Smugglers may respond to an increase in interdiction intensity that is perceived to be relatively short-term by increasing holdings in the source country. This appears to have occurred during Hat Trick II. Both marijuana and cocaine can be stored for six months with only moderate loss of quality. The decision of whether to hold higher source country inventories or incur the increased risk of seizure is a function of the expected duration of the blockade, the imputed cost of capital, the source country price of the drugs, and the anticipated differential between blockade and post-blockade import prices.

The anticipated price differential may be importantly determined by the size of U.S. drug inventories, both distributor and consumer inventories. If inventories are large and the sharp diminution in imports is perceived to be short-lived, price changes are likely to be modest. If there is evidence that U.S. inventories are adequate for, say, six months' consumption, prices may be expected to rise only modestly during a blockade of three months and source-country holdings will rise sharply. Some interviews with convicted wholesalers suggest that U.S. inventories of cocaine are likely to be a few weeks' supply rather than a few months', but the evidence is very skimpy.

If U.S. inventories are indeed modest, then an effective blockade should lead to an increase in U.S. retail prices. In fact, no such increase was observed after the Hat Trick operations.

Finally, we should note the impact of changes in source country exchange rates on the dollar price of exports, since the available data report only dollar prices. Assume that all risks and costs associated with production in source countries stay the same but that the exchange rate for the Colombian peso falls. Changes in exchange rates that reflect differential inflation rates in the United States and source countries will probably lead to no change in source country export prices expressed in dollars. However, if the exchange rate of the Colombian currency declines for reasons other than inflation, the long-run dollar price for Colombian marijuana should also decline. As it turns out, adjusting for inflation, the real exchange rate for the Colombian peso appears to have been fairly stable over the period 1980 to 1985. Exchange rate variation is probably not a major factor in export prices for cocaine and imported marijuana.[21]

In summary, interdiction may have an impact on export prices, both in the short and the long run. The direction of effects is difficult to predict but is likely to be positive for cocaine and negative for marijuana, where domestic production is an important response. It is plausible that these effects are modest, but more research is required before a firm conclusion is drawn.

ALTERNATIVE MEASURES OF INTERDICTION EFFECTIVENESS

Our focus on price as a method of evaluation is somewhat novel. In the following, we consider other measures of interdiction program effectiveness that have been used in the past.

The first issue is a conceptual one. What do we mean by interdiction effectiveness? Since the primary objective of interdiction is to reduce consumption of certain drugs in the United States, we need a measure that relates to consumption.

The quantity of drug shipments seized, the most commonly cited (and readily calculated) measure, is not likely to be appropriate. Even the use of seizure rates, the percentage of the quantity shipped that is seized through interdiction, can be misleading. At one extreme, effective interdiction will lead to no shipments and consequently no

[21]This is by no means a complete analysis of the exchange rate issue. For example, we have not factored in changes in Bolivian and Peruvian exchange rates, which also affect the prices of Colombian exports.

seizures. Moreover, this extreme is not a bizarre academic possibility; in the case of marijuana, highly effective interdiction against foreign sources might lead to full displacement by higher-cost domestic sources. In recent years there has been a decline in the seizure quantity and seizure rate for marijuana; yet it may well be that marijuana interdiction has actually had more impact on consumption than it did in earlier years.

Similarly, very high seizure rates are compatible with relatively ineffective interdiction. This is a more academic possibility, but it does pose some interesting issues. Consider, for example, a drug transportation system that uses marine drones, i.e., the drug is placed on an automated platform and programmed to travel to a particular point on or near the U.S. coast. The export price of the drug is very low and, in this future world, the platforms can be bought at the local Radio Shack for $100. The optimal transportation mode might be use of these marine drones, even though a very high percentage of them are intercepted; this would be the case if the alternative modes of transportation were very much more expensive. But the cost of getting the drugs from source countries to the United States might still be a modest fraction of final price. Interdiction would then have little impact on consumption, even though it produces a high seizure rate.

This latter model provides some insight into recent cocaine smuggling patterns, as discussed in Section V. The larger quantities seized may simply reflect the fact that the export price of the drug is lower and hence it is optimal to invest less in evasive activities.

OBJECTIONS TO THE PRICE CRITERION

The use of prices, or price markups, as a measure of the efficacy of enforcement is a matter of some dispute. At a project conference, interdiction agency representatives and some academics argued against price as a performance criterion, for three principal reasons: First, it was asserted that there is so much variation in the price paid at any one time at a given level of the market that one simply cannot refer to "the" price. That objection was discussed earlier in this section. We believe that the data presented there (and analyzed in more detail in Appendix B) provide evidence that price is a meaningful term in high-level drug markets.

The second objection asserts that interdiction activities have impacts beyond the point of importation that are not captured in the import price. For example, the arrest of the agents of smugglers imposes risks on their customers, e.g., the agents can put the customers at risk in bargaining for freedom or reduced sentences.

We attempted to test this by seeking data on the frequency with which domestic cases were made as the result of information provided from interdiction cases. The relevant domestic investigative agency, the DEA, responded to our query by saying that only a negligible number of their investigations had origins in interdiction seizures. In light of this, we believe that interdiction programs have little effect on downstream distributor risks.

Also, as imports become more unpredictable in their timing (as a result of seizures), wholesalers are forced to do more searching for sources of supplies, thereby increasing their exposure to enforcement. It is not possible to test this hypothesis, since domestic arrest rates in any area cannot be readily related to the frequency of interdiction successes in that region. However, the relatively stable price data reported for high-level cocaine transactions in the past two years (despite large seizures) are inconsistent with the hypothesis.

The third objection to use of price as a measure of enforcement efficacy is that it is not an operational criterion for evaluating agency performance on a real-time basis. Certainly the price data can be developed only with a lag, and they inevitably have a significant observational error. However, our analysis is intended for high-level policy use, and we do not mean to imply that the same criterion should be used for field evaluation of the performance of a particular unit.

CONCLUSIONS

Interdiction has complex effects on the distribution and use of drugs. Export prices may be raised or lowered, the flow of drugs may become more uncertain, etc. We believe that the major effect of increased interdiction stringency can be captured in its impact on the difference between import and export prices. By raising the costs of smuggling drugs into the United States, increased interdiction will increase the price that users have to pay. That in turn will lead to a reduction in total consumption of imported drugs.

Data are lacking on many of the elements of the relationships among interdiction stringency, smuggler costs, and consumption. In our empirical work, we have had to make numerous judgments that rely on anecdotes and soft data. Nonetheless, a focus on price will increase understanding of the effect of increased interdiction efforts.

III. DRUG SMUGGLING, THE INTERDICTION PROCESS, AND THE ROLE OF INTELLIGENCE

We begin this section with a brief description of the routes and modes used for cocaine and marijuana smuggling.[1] We also present some information on organization and adaptation in drug smuggling. The structure and operation of the interdiction program are then described, and the section concludes with an analysis of the role of intelligence in interdiction.

SMUGGLING: ROUTES AND ADAPTATION

Cocaine Smuggling Routes

Cocaine is produced in three countries: Bolivia, Colombia, and Peru.[2] The bulk of U.S.-destined cocaine is exported from Colombia, where the refining facilities are located. Faced with increased interdiction threats on the direct Colombia-U.S. routes, smugglers have begun to transship through Mexico. Most of the shipments into the United States from Mexico are made by private aircraft flying over the land border, where they appear to be less vulnerable to interdiction.[3]

It is believed that the majority of cocaine is smuggled by air—some in commercial flights, more, probably, in small, privately owned aircraft. In 1985, for the first time, the Coast Guard reported significant quantities of cocaine (3,000 kilograms) seized on vessels; this is believed to represent a change in cocaine trafficking patterns rather than a change in search procedures.

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[1]More detail on these can be found in publications of the National Narcotics Intelligence Consumers Committee (NNICC) and the DEA. Each year since 1978, the NNICC has published a *Narcotics Intelligence Estimate*, which presents estimates of quantities of various drugs, along with descriptions of changes in drug trafficking patterns.

[2]There is evidence of development of coca fields in Brazil. A major U.S. trafficking organization using Brazilian refined cocaine was recently uncovered (*Washington Post*, March 10, 1987, p. 3), but it is likely that this is oriented primarily toward European markets. See the *Annual Reports* of the Bureau of International Narcotics Matters (Department of State) concerning production developments in Latin America.

[3]There is some evidence of increasing use of land and sea routes for moving cocaine from Mexico to the United States.

Marijuana Smuggling

Marijuana comes from a more dispersed set of sources than does cocaine. Farmers in Colombia, Mexico, and Jamaica account for most of the imports; Belize is a lesser source, which has become active in recent years. Shipments are almost all directly from the source countries rather than through transshipment countries, although the Bahamas serve as a transshipment point for some Colombian traffic. Some higher-quality marijuana and hashish, a purified form of the drug, are imported from more remote sources, such as Thailand and Morocco. However, these drugs are thought to account for a small share of total imports.

Marijuana is smuggled by air, land, and sea. Considerable quantities of Mexican marijuana apparently enter across the land border, either in small bundles carried by individuals or in slightly larger bundles carried in vehicles. Marijuana from Colombia is primarily seaborne, while that from Jamaica and Belize is probably delivered primarily in general aviation aircraft. Some Jamaican marijuana is transshipped through the Bahamas.

Most interdicted marijuana, like cocaine, is either on its way to, or captured in, southern Florida. This is true for both air and sea shipments. The sea routes from Colombia usually involve transit through various Caribbean "choke points," relatively narrow channels between major islands. Increased interdiction efforts have led to more traffic going farther east in the Caribbean, into less protected waters, and landing farther north than Florida. But interdiction agencies still believe that most of the cocaine and marijuana imported into the United States enters through southern Florida and that most of the sea traffic passes through the Yucatan, Mona, and Windward channels.

A significant share of U.S. marijuana consumption is supplied domestically. The domestic sector appears to have grown rapidly since about 1980, though estimates of its size are highly conjectural. The development of domestic production may be seen as a consequence of interdiction, a matter we discuss in Section VIII.

Organizations

Little is known about the organization of the drug smuggling business. It is often asserted that the Colombian export sector is controlled by a small number of Colombian families. Similar statements have also been made about the Mexican marijuana trade. Even if those statements are correct, it is unclear whether the exporters are also the smugglers, or whether they sell the drugs to separate, specialized, smuggling organizations.

For this study, it would have been useful to have information on whether smuggling organizations are specialized with respect to routes, drugs, and forms of transportation. In the simulation model presented in Section VI, we assume that changes in the riskiness of particular methods and routes of smuggling feed back into changes in the distribution of attempted smuggling efforts across the set of methods and routes. This feedback is likely to be more immediate if it is not worked through the market, but is acquired through individual organizations that use all the available means of bringing the drugs into the United States. But even without this intraorganizational intelligence, i.e., even if individual smuggling organizations specialize in particular smuggling paths, the feedback can be attained through market forces.[4]

There is no available published information on such matters. The best anecdotal study (Warner, 1986) deals with smuggling organizations of the late 1970s and is narrow in scope. We did not obtain any relevant information from agencies.

Smuggler Adaptations

As noted in Section I, earlier modeling efforts have ignored adaptations by smugglers to changes in interdiction strategies and intensities. Yet the historical evidence, though by no means well documented, suggests that adaptation has been significant.

Three instances of large-scale adaptation can be cited. First, increased marine interdiction of marijuana since the late 1970s appears to have led to a scaling down of the size of individual shipments. This has lowered the average risk (per kilogram shipped) for the individual smuggler and has also reduced the probability of seizure of any individual shipment, as a result of increases in the number of targets.[5]

Second, increased air interdiction against cocaine smugglers has led to the development of Mexico as a transshipment point. This adaptation was also motivated by the increasing difficulty of obtaining processing chemicals in Colombia, which has made Mexico more attractive as a processing location. The Mexican border is probably the most vulnerable entry area for smuggling, whether by land or by air.

[4]For example, as the price of one mode of transport rises, the price charged by smugglers using that mode will also rise. Smugglers using other modes will find that the demand for their services increases as a result. Given the impediments to the flow of information in illegal markets, this may take a relatively long period to work through.

[5]An increase in the risk of seizure will lead risk-averse smugglers to ship in smaller lot sizes. The assumption of risk-aversion is not obviously appropriate for smugglers, but less stringent assumptions (e.g., declining relative risk-aversion) will do as well. Moreover, the same result can come from strategic decisions by smugglers as a group responding to the increased risk.

Third, and more speculative, the increased severity of air interdiction of cocaine has led to a shift to marine transportation, as indicated by recent cocaine seizures by the Coast Guard. Because cocaine is compact per unit value, it can be secreted in compartments that are not readily discovered by interdicting personnel.[6] Thus, cocaine smuggled by sea may be much less vulnerable to seizure than marijuana brought in the same way.

These adaptations should not be taken as evidence of omniscience or great ingenuity on the part of smugglers. They have occurred over significant lengths of time and may be less than optimal. Nonetheless, they do point to the need to take major adaptations by smugglers into account when considering the efficacy of enhanced interdiction.

A final point should be made concerning smuggling costs. Pure transportation equipment costs appear to be a very modest share of total drug distribution costs, even compared with the import price. Consider a worst-case scenario for a cocaine smuggler, in which he must (a) purchase, rather than rent, a plane, and (b) abandon the plane after a single use. The cost of a used twin-engine plane in good condition and with the necessary range to cross the Mexican border is not more than $100,000.[7] If the shipment consists of 250 kilograms (approximately the mean seizure from private planes in 1985), the cost of the plane is about $400 per kilogram, while the import price is approximately $30,000 per kilogram.

A similar calculation can be made for marijuana. The cost of a vessel adequate to bring in 5 tons of marijuana (the average size of a Coast Guard seizure) is certainly less than $100,000.[8] If that entire cost is to be allocated to a single shipment, the pure transportation equipment cost is approximately $20 per kilogram, whereas the import price is approximately $500 per kilogram.

It should be noted that both of these are worst-case calculations, from the smuggler's point of view; it may well be possible to rent a plane (or even a boat) for single trips, without greatly increasing the probability of arrest. The smuggler then puts at risk only the rental cost of the plane or boat.

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[6]A Customs officer told of concealment that led the agency to miss the main cache and to sell the boat at an auction. The original smugglers bought it back and only then was the hiding place discovered. New inspection technologies (OTA, 1986) may reduce the advantage of cocaine smuggling in this form.

[7]Advertisements for used planes in a recent issue of *Trade-a-Plane* offered several suitable planes for less than $100,000.

[8]A review of *Washington Post* advertisements for the kinds of recreational boats that are involved in smuggling indicated many available for $50,000.

This strongly suggests that interdiction efforts that can be defeated by incurring higher transportation costs are likely to do little to raise the costs of smuggling, and hence do little to reduce the consumption of the drugs. In particular, if the intelligence system ensures that any vessel or plane used once for smuggling is certain to be caught the next time, there are not likely to be observable consequences for the landed price of marijuana or cocaine, unless smugglers are unaware of the certainty of getting caught. The same statement holds if a new detection system can be weakened by adding special equipment to planes, unless that equipment is very much more expensive than current transportation modes and/or cannot be readily obtained in market transactions. This conclusion is particularly significant for air smuggling.

INTERDICTION RESOURCES: NONMILITARY

A brief description of the assets that are used by the current interdiction agencies is essential to understanding the potential military role in interdiction, since much of what the military can do consists of supplying specialized assets. We are also interested in identifying those resources that appear to constrain the efficacy of the system. Each element of the interdiction system involves combinations of resources, and some parts of the system cannot be usefully expanded without increasing certain other resources.

The interdiction system is not a single entity. The binding constraint may be different for different locations or for different media (air, land, or sea). We hazard the opinion that for marine interdiction, the binding constraint is the number of platforms (i.e., vessels that can bring arresting officers in contact with the smuggler), while for air interdiction, surveillance is also a significant constraint. Lack of intelligence also may serve to constrain all components of the system.

Marine Interdiction

The Coast Guard, an agency within the Department of Transportation, is the prime marine interdiction agency on the high seas. It devotes approximately 20 percent of its resources to drug interdiction,[9] and 80 percent of those resources are deployed in the Gulf and South Florida Coast Guard districts. Its seizures are primarily of marijuana; over the last six years, the quantity of marijuana seized by the agency has gradually declined.

[9]Precise calculation is impossible because so many of the Coast Guard patrols are multipurpose: drug interdiction, fishery law enforcement, sea rescue, etc.

There are two primary reasons for the decrease in marijuana seizures by the Coast Guard, despite a massive increase in its commitment to interdiction (from approximately \$140 million in fiscal year 1979 to \$350 million in fiscal year 1985, not including acquisition expenditures). First, as already noted, there has been a scaling down of the size of individual shipments. In fiscal year 1978, the Coast Guard seized 133 vessels with 3.0 million pounds of marijuana; the average seizure was 22,300 pounds (approximately 10.1 metric tons). In fiscal year 1985, 184 vessels were seized, with a total of 1.9 million pounds of marijuana; the average seizure was only 10,100 pounds (approximately 4.5 metric tons), less than half the volume of 1978.[10] As already suggested, the scaling down of shipment size is an expected response to increased interdiction intensity, and it leads to a reduction in the effectiveness of any level of marine interdiction effort, since the same resources are required to interdict a 5-ton shipment as to interdict a 10-ton shipment.

Second, the bulk of the time devoted to interdiction is spent in transit to and from the interdiction point. The only available estimate, based on 1978 data, suggests that a Coast Guard boat spends only 18 percent of its interdiction time actually in patrol and seizure activities in the designated area. The legal requirement that captured crewmen be promptly returned to the United States for processing within the criminal justice system, as well as the fact that many seized vessels are not in seaworthy condition, forces Coast Guard vessels to leave their patrol stations soon after any smugglers are captured. In addition, the patrol stations are sometimes quite distant from the cutter's home port, so a considerable amount of time is spent transiting to and from the station.

The Coast Guard conducts most of its interdiction activities outside U.S. territorial waters. The dominant strategy has been to focus efforts on the choke points (the four major channels through which seaborne Colombia-source marijuana must transit) and/or close to the point of departure (as in the Hat Trick I and Hat Trick II operations).

The Coast Guard has a total of approximately 80 vessels in the Atlantic Ocean capable of seagoing patrol (cutters 65 feet or more in length). In the Pacific, where a small proportion of Coast Guard drug seizures take place, there are an additional 44 such vessels. Though some smuggling activity does occur on the West Coast, the trip from Colombia is longer, involves more hazardous waters, and offers fewer

[10]Though there is some year-to-year fluctuation, the size of the average shipment follows a clearly declining trend.

points of concealment than transit along Caribbean routes. It is unlikely that much marijuana is imported this way.

The Coast Guard also has 112 planes in the Atlantic and another 53 in the Pacific. The planes are used as spotters for vessels; they carry radar and often close on vessels to make an identification. The aircraft are not used to make the actual seizures.

The numbers of oceangoing Coast Guard vessels are significant in the current context because the total productivity of the fleet is heavily influenced by the number of "platforms." Conversations with Coast Guard and Naval personnel indicate that Coast Guard cutters may be just as effective as very large and sophisticated ships, such as Navy destroyers, in interdicting vessels of the type used for smuggling marijuana. All that is required is a vessel that can stay on patrol for a reasonable number of days, has sufficient radar and other electronic equipment to permit distant surveillance, and has adequate speed to overtake an identified target within a reasonable period of time. The Navy's contribution to interdiction (as opposed to detection) is largely determined by the number of ships that it can provide. The locus of most routine Navy training operations in the West Atlantic and Caribbean does not fit conveniently with drug interdiction choke and entry points. Hence it is difficult for the Navy to provide a significant increase in the number of effectively available platforms.

Marine patrol closer to the U.S. coast is handled by the U.S. Customs Service Marine Division.[11] Customs has over 150 vessels deployed at 11 marine "modules." Seven of these modules are on the Florida coast. The Customs boats, because of their location and the nature of their adversary, are small and many of them are very fast.[12] They are integrated with shore-based surveillance systems but do not have their own air support units. Customs marine seizures have been of the same magnitude as those of the Coast Guard in recent years.[13] The Coast Guard also provides significant interdiction effort in U.S. coastal waters.

As mentioned in Section I, some formal studies have suggested that the major weakness of the marine interdiction system is the low percentage of smugglers detected. But no estimates have been made of the percentage of smugglers that evade sighting at all, as distinguished

[11]The Customs Service's legal mandate restricts it to activities within the 12-mile limit that defines U.S. national waters.

[12]Details of the capabilities of new equipment acquired by the Customs Marine Division are given in OTA (1986).

[13]Some question has been raised as to whether the Customs seizure totals reflect a significant amount of double counting, since the Coast Guard turns over many of its seizures to Customs agents for legal processing.

from those that are sighted but incorrectly identified as nonsmugglers. This, as we shall see, is significant when we consider the possibility of adding military detection resources. The available vessels are thought to have the requisite pursuit capability, once the decision to pursue has been made.

Air Interdiction

The Customs Service is the agency with primary responsibility for interdiction of drugs smuggled by air. It has assembled an Air Branch of 78 planes, 41 of which were seized from smugglers. The large number of seized planes ensures that the fleet is very heterogeneous; some of the planes, however, are considered inadequate for the interdiction function (OTA, 1986). The air fleet includes some helicopters and jets, as well as slower fixed-wing prop planes.

Small planes enter the United States at many points along the Southern border. The south Florida coast has historically been the prime entry area, and most of the Customs Air Branch resources have been concentrated there. The flat topography of the area and the smuggler's necessity of flying across water for at least 50 miles make this an excellent area for the use of radar. Many flights are thought to provide drops to small, high-speed boats that may evade detection close to the coast.

On the land border, particularly in Texas and Arizona, the interdictors are aiming at a very different kind of traffic. The terrain is very uneven (as well as lightly inhabited), and there are numerous airstrips just south of the border.

The process of air interdiction, unlike marine interdiction, has not been formally studied, so less is known about the component probabilities (detection, identification, etc.). However, it is clear that the probability of detection is very low over large segments of the Mexican border. Since these areas have not been important for legal civil air traffic or of concern to the military, little effort has been made to install radar equipment. The decision to install tethered aerostats along the Southwest border will change this, but in interpreting the past it is important to note that this area has been subject to little radar coverage.

Given the lack of surveillance efforts and the uncertainty about shipment levels, any estimate of sighting probability is highly conjectural, but it would be surprising if that probability along some stretches of the border were greater than 10 percent. Others have concluded that increasing this probability would probably substantially improve the performance of the air interdiction system. The OTA (1986,

pp. 5–43) estimated that, for the system as a whole (i.e., for all borders), the probability of sighting and identifying a drug-carrying aircraft was not higher than 16 percent. For the Mexican border, it is likely to be much lower.

The proposed installation of a number of tethered aerostats should provide some improvement in detection performance, but even when a smuggler is seen on a radar screen, the probability of identifying the plane as a target is not high. Smugglers who choose to cancel an international instrument flight plan and proceed on a visual flight plan, or those entering the country on a visual flight plan, could land at an alternate airport for a rapid unloading and be at risk for a very short period of time. Moreover, smugglers could choose to flood an area with diversionary targets fitting a smuggler profile and draw off significant pursuit capacity. The major improvements in the performance of the air interdiction system may come less from improved detection and pursuit resources than from tighter restrictions on the flights of nonsmugglers, e.g., extending the time period required for reporting penetration and arrival of the continental U.S. airspace. Tighter restrictions are being contemplated by the Federal Aviation Administration (FAA); these would permit better sorting of targets, though they would increase effectiveness only slightly against the specific techniques we have just described.

Land Interdiction

Perhaps the lowest-risk mode of smuggling is that of crossing the U.S.-Mexico land border. Customs and the INS have primary responsibility at this border. Within the last year, the INS has taken the lead from Customs; many INS agents have been given a cross-designation as Customs agents, thus permitting them to search vehicles and persons solely on suspicion of drugs. Only about 3 percent of the interdicted cocaine was seized on the land border and only about 6 percent of the major marijuana border seizures were made there (U.S. Congress, 1985, p. 612).

Too little information is available concerning land smuggling to permit statements about the various conditional probabilities. Land sensor technologies are being developed that might permit interdiction agencies to significantly raise the probability of detection of land crossing, but the feasibility of deploying these on a large scale and supporting them with effective pursuit resources remains unknown.

The critical issue concerning the potential military role in land interdiction is the extent of land smuggling that does not pass through ports of entry. Better radar coverage of the border may assist in

forcing land smugglers to use port-of-entry routes, e.g., concealing drugs in trucks carrying fresh produce. This can be done for both marijuana and cocaine, though it is significantly more difficult for marijuana, because of its bulk and its distinctive odor.[14] Port-of-entry smuggling, particularly of cocaine, is unlikely to be an activity for which current military assets can improve interdiction, though there are new technologies (e.g., antibody/antigen detection) in which the military services are versed and which may increase the detection rate for port-of-entry inspection.

INTELLIGENCE

Drug interdiction, like any other interdiction activity, can be enhanced by prior information about the location, path, and identity of targets. Such generic intelligence plays a significant role in the drug interdiction program. To understand the potential impact of increased military involvement, we must first analyze the role of intelligence.

This point may be illustrated by a hypothetical example. Assume that 60 percent of current interdiction successes are the result of intelligence; the other 40 percent result from pure patrol, which, of course, includes the use of target profiles in decisions about which persons or vehicles to pursue. Assume, also, that all targets identified by prior intelligence are in fact seized, and that the activities associated with obtaining these targets use only 10 percent of the interdictors' capacities, the remainder being used for patrol activities.

If, in this situation, the military were to provide increased surveillance and pursuit capacity but no additional intelligence, its resources would improve the performance of only the patrol function. If, as a result of the military involvement, the number of vessels searched by patrol is doubled, then the aggregate number of seizures, ignoring possible adaptations, will rise by only about 40 percent. An analysis that did not take account of the role of intelligence would infer that seizures might double with the additional military resources.

Similarly, analyses that fail to distinguish between intelligence and patrol successes will assume that the current risks to smugglers from patrol are higher than they actually are. For example, the percentage of patrol targets that are sighted and correctly identified will be overestimated.

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[14]Smugglers have attempted to overcome this problem for many years by concealing the marijuana within other bulk cargo that has its own distinctive odor. Adler (1985) provides some interesting examples of these efforts.

This is, of course, a hypothetical situation. We have only limited data on the successful use of intelligence, but the example does point to the potential importance of distinguishing between interdiction using patrol targets and interdiction based on intelligence. We next describe the varieties of intelligence that are used in interdiction and discuss what we have learned about the successful utilization of this intelligence.

The Varieties of Intelligence

Intelligence can take many forms, but they all fall into one of two broad categories: human intelligence or technical intelligence.

Human Intelligence. Individuals sometimes provide information about persons or vessels involved in smuggling. For example, an airport employee in the United States might notify Customs that a certain plane has added new fuel tanks to extend its range, without FAA approval. Or a marina employee may notify the Customs Marine Branch that a certain boat appears to be about to leave on a smuggling trip. Intelligence agencies then add that plane or vehicle to the list of those that bear close scrutiny, noting, if possible, a place and time at which the vessel is likely to be found in the act of smuggling.

The motivations of informants are as varied as their information; revenge, public-spiritedness, and the opportunity to curry favor with authorities all play a role. The significant point here is that human intelligence cannot be much augmented by military involvement, although its utilization might be improved.

Technical Intelligence. Both the Coast Guard and the Customs Service conduct various kinds of sensitive or classified programs, sometimes using the assets of other agencies, to collect intelligence. For example, a plane may photograph on successive days a port that is thought to hold several smuggling vessels. By comparing the photographs, it is possible to establish that a boat with a particular configuration left the port within a certain 24-hour period. This provides some targeting information for Coast Guard patrols.

Again, there is a considerable variety of technical intelligence sources, which provide a wide range of information. The military can probably significantly augment the technical intelligence available for drug interdiction. However, we were not able to explore this subject in detail—nor, as will become clear, was there any strong reason for doing so.

Before moving to an evaluation of the role of intelligence, we must note that there is enormous range in its specificity. Some is highly specific: "The SS Star left Santa Maria with 50 tons of marijuana at

11 pm on December 7, heading toward the Yucatan Channel." Some is very general: "There has been an increase in nighttime departures from the Guadalajara Peninsula in the last week." The value of the intelligence is obviously a function of its specificity. The first piece of intelligence, if provided by a reliable source, permits the targeting of resources in a relatively narrow area with a very well described target in a short period of time. The second will simply affect decisions about the general allocation of pursuit resources across a broad range of time and area. Specific intelligence is more valuable than general intelligence.

The Performance of the Intelligence System

Interdiction intelligence is centralized in the El Paso Interdiction Center (EPIC), an interagency organization headed by the DEA. All the interdiction agencies, plus other agencies such as the Internal Revenue Service and the Army Intelligence Corps, have personnel at EPIC and provide access to their major intelligence databases. EPIC, in turn, provides real-time response to requests from the agencies for information about specific targets.

A Coast Guard commander may query EPIC for information about a vessel that he has identified. Within an hour, and often in even less time, EPIC will report whether that ship is listed as a suspect vessel, using the term *suspect* broadly.

EPIC maintains very large lists of suspect vessels, planes, persons, etc. Over 17,000 planes, identified by tail number, manufacture, alteration, etc., are included on the air list; a similar number of boats and ships make up the maritime list.

The role of EPIC, and of intelligence generally, in drug interdiction has been a matter of some controversy. The National Drug Enforcement Policy Board (1986, p. 129) estimated that 61.3 percent of the marijuana seized in fiscal year 1985 was seized as the result of intelligence; for cocaine, the figure was 63.5 percent. Other sources show higher estimates. There have routinely been complaints that domestic investigative agencies fail to provide adequate intelligence to interdiction agencies.

Coast Guard Utilization of Intelligence

Since early 1986, the Coast Guard has maintained a database on the patrol activities of its vessels and aircraft in the Atlantic. All units are required to provide information on sighting, pursuit, boardings, etc.

The dataset is called SEER (Summary Event Enforcement Report) and is maintained at the Coast Guard computer center in New York.

At the request of the DoD, the Coast Guard provided RAND with certain summary data for fiscal year 1986 for the entire Atlantic region. For purposes of analysis, that region was broken up into 10 distinct areas, corresponding to different segments of possible maritime smuggling routes. The information for each area included the number of patrols, detections, identifications, boardings, and drug seizures. Data were also provided on the number of identified vessels for which there was prior information about possible drug-carrying.[15]

Table 3.1 presents, for the drug smuggling areas, summary data on the probabilities of various events following the detection of a vessel, whether the detection was made from a ship or a helicopter. Most significant for this study are data concerning the impact of prior intelligence that a particular vessel might be drug-carrying. Overall, the dataset included some 125 vessels boarded for which there was prior information leading them to be classified as drug suspect. Of these 125, only 16 were actually found to be carrying drugs, i.e., the probability that a vessel would turn out to be carrying drugs was only .128.

One interpretation of that figure is that the intelligence system is inefficient. After all, it seems reasonable to expect that a list of targets would be able to yield more than a one-in-eight hit rate when a target is boarded. There are two important qualifications to this judgment.

First, it is useful to compare the success rate for intelligence boardings against the rate of those where the vessel is boarded without any prior intelligence to suggest that it is suspect (i.e., "patrol" boardings). Drugs were found on only 2.6 percent of the patrol boardings for which there was no prior drug information—barely one-fifth the rate for identified suspects.[16] Intelligence appears to substantially improve the

[15]Three qualifications must be made about these data: First, there is undoubtedly some double counting at various points. A vessel that was detected by one cutter or aircraft at an early stage of its voyage may later be identified by another cutter or aircraft; this would show up as two detections. Second, the system does not include the smaller, near-shore patrol boats; thus it does not provide a complete measure of the risks to smugglers imposed by the Coast Guard. Third, the data system is a new one and errors may arise from ship personnel's lack of familiarity with reporting requirements. Nonetheless, the system should provide reasonable estimates of probabilities of various events following pursuit.

[16]Because the Coast Guard boards vessels to investigate matters other than drug smuggling, the 2.6 percent may understate the success rate of patrol-generated boardings for drug violations. However, given that drug surveillance is the prime function of the Coast Guard in the areas from which these data come, we doubt that the error is a large one.

Table 3.1

COAST GUARD SEIZURES AND THE ROLE OF INTELLIGENCE: FISCAL YEAR 1986

1. Total number of patrols	1,564
2. Number of vessels detected	35,134
3. Number of vessels identified	13,017
4. Number of vessels boarded	1,009
5. Number boarded with drug violations	39
6. Of those identified, number with prior information regarding drugs	238
7. Of those with prior drug information, number boarded	125
8. Number with prior drug information with drug violations	16
9. Prob. of identification, given detection (3/2)	0.370
10. Prob. of drug violation, given boarding (5/4)	0.039
11. Prob. of drug violation, given prior drug information and boarding (8/7)	0.128
12. Prob. of drug violation without prior drug information, given boarding (5-8) / (4-7)	0.026
13. Percent of boardings with prior drug information of all boardings (7/4) × 100	12.4
14. Percent of number of vessels boarded with prior drug information of all with prior drug information (7/6) × 100	52.5

SOURCE: Summary Enforcement Event Report data. The data cover only cutters of more than 65 feet operating on the East Coast. Patrol and identification numbers include aircraft patrol activity as well.

success of Coast Guard interdiction as compared with a pure patrol strategy.[17]

Second, there is substantial diversity among the vessels that are appropriate for drug smuggling. Drugs have been found aboard many kinds of pleasure and fishing boats, and the book of suspect profiles is extremely thick. There is no reason to expect that a vessel which was once used for drug trafficking would continue in that role for the rest of its useful life. Indeed, the cautious smuggler would presumably wish

[17]We cannot make a stronger statement than "a‚ ,ears," because the intelligence targets might have a different profile from the other traffic. Absent prior intelligence, experienced captains might still be able to pull these targets from the rest of the traffic. That seems unlikely however, given the great diversity of types of vessels used for smuggling.

to change boats as frequently as possible. Thus a list based on past information about smuggling is likely to include many boats no longer actively involved in that activity.

It is also important to note the numbers of seizures resulting from prior intelligence and those from pure patrol. Of the 39 seizures in the SEER database, 23 were the result of patrol. This figure is consistent with the Drug Enforcement Policy Board's 1986 statement that 50 percent of the Coast Guard's "mother ship" seizures were made as a result of intelligence in fiscal years 1984 and 1985. Intelligence seizures have a higher average weight of marijuana than do patrol seizures; thus intelligence accounts for a higher share of the weight seized than of the number of seizures.

In summary, intelligence seems to enhance the productivity of Coast Guard interdiction, but patrol activity is still critical. Moreover, intelligence is not highly specific, i.e., it assists in sorting rather than in directing patrol.

Intelligence in the Air Interdiction Process

Intelligence is of only very slight importance for the interdiction of air smugglers.[18] EPIC reports very few planes caught as a result of its intelligence efforts, though a significant share of the planes caught turn out afterward to have been on the EPIC suspect list. The small role of prior intelligence appears to be not so much the result of weaknesses in the intelligence process as of the short period of vulnerability of air smugglers.

Unlike marine targets, which may be visible for days, air smugglers are visible for only a few minutes to a few hours. A plane coming over the Mexican border may launch from a strip less than 50 miles south of the border and land less than 50 miles north of it. Even with instant radar detection, the plane will have been in U.S. airspace for no more than 30 minutes prior to its unloading in the United States, during which time a pursuit aircraft will have had to launch and close to obtain a visual sighting, relay its information back to EPIC, and learn whether the plane is on the suspect list.

The smuggler's plane, if he chooses to land, can be unloaded within a few minutes and then flown back into Mexican airspace. It cannot be stopped once it launches on its return trip, since interdiction agencies may not force a plane down—this risks endangering the pilot, a

[18]Customs Air Branch officials in the southwest claim to rely heavily on intelligence. However, the available data suggest that this region makes very few seizures. Intelligence is apparently not important for the Southeast Air Branch, which accounts for most of the seizures.

contingency that has been realized on at least one occasion. The Mexican authorities will not generally pursue a plane after it is back in Mexican territory.

This discussion should not be interpreted as suggesting that air smugglers are invulnerable. Some get caught, either through carelessness or because they undertake longer trips—for example, from Colombia—during which they are vulnerable to interdiction for a longer period of time. But it does suggest the limitations of intelligence in the air interdiction process. The intelligence needs to be highly specific as to time and location if it is to have any effect at all. The current system does not generate much intelligence with that degree of specificity. Given smugglers' flexibility, it seems unlikely that this can be changed very much.

CONCLUSIONS

Intelligence has a rather limited role in the interdiction process. The types of intelligence currently available clearly enhance marine interdiction, but that activity is still very much driven by patrol. Coast Guard interdiction success does not seem to be primarily the result of purposive search for prior identified targets. For air interdiction, intelligence plays a very minor part. Land interdiction has as yet yielded too few seizures to permit an assessment of the role of intelligence there.

Our assessment, admittedly subjective, is that the drug smuggling process is not one for which intelligence is likely to play a very large role. There are simply too many places, routes, and times of entry available to smuggling organizations and, at least for air interdiction, too short a time in which to make use of intelligence. The equipment needs are also not highly specific, so suspect equipment lists (a principal component of the intelligence process) provide little assistance to interdictors. Highly specific human intelligence, notoriously hard to generate in large quantities, appears to be the only kind of intelligence that could significantly improve the performance of the system.

IV. MILITARY CONTRIBUTIONS TO INTERDICTION

The DoD has been involved in the drug interdiction program since at least 1971. Its assistance prior to 1981 was, however, sporadic and uncoordinated. As an example, the GAO (1983) cites a program in which the Navy agreed to provide information to the Coast Guard on any sightings of drug smuggling ships; the Coast Guard obtained only three seizures as a result of this program. A more troubling instance concerned the use of advanced warning and control systems (AWACS): "From August 1978 through September 1979, Customs personnel participated in 97 AWACS flights that detected 268 potential targets. Customs aircraft intercepted 31 of these targets, but none . . . proved to be a smuggling target" (p. 78).

Changes in the Posse Comitatus Act (18 U.S.C. 1385) have permitted increasing DoD involvement. Prior to 1981, the Act had restricted the military to the provision of "indirect" or "passive" assistance to domestic law enforcement—the terms were undefined. Explicit authority was provided in 1981, under PL 97-86, for the military to furnish support for interdiction agencies. In the past two years Congress has also made substantial appropriations in the DoD budget for the acquisition of equipment to be used specifically in the drug interdiction program.

This section begins with a review of the history of DoD outlays on drug interdiction. This is followed by a description of the coordinating mechanisms by which military assets and personnel are brought into support of interdiction. The section concludes with more detailed analyses of the impact of this support, particularly in air interdiction.

MILITARY DRUG INTERDICTION EXPENDITURES

In terms of expenditures, the military contribution has, at least until very recently, been extremely modest. The Office of Management and Budget (OMB) estimated in May 1985 that the DoD had spent $15.8 million in fiscal year 1984 and $14.6 million in fiscal year 1985 in support of interdiction; equipment on loan was valued at that time at $88 million (President's Commission on Organized Crime, 1986, App. E). Preliminary and unpublished estimates of DoD expenditures, both past and future, report significantly higher figures for these years—for 1985,

the DoD estimate is $55 million. However, these figures are still very small compared with the approximately $600 million to $700 million interdiction expenditures of nonmilitary agencies (see Table 5.1 in Section V).

The recency of large military interdiction expenditures, as well as the time needed to integrate the military and its equipment into the drug interdiction program, make it difficult to use the past to assess how much military efforts will eventually increase the effectiveness of the interdiction programs. Though there have been large increases in authorized expenditures for fiscal years 1986 and 1987, most of these are for equipment acquisition, discussed below; they will not improve actual interdiction performance for some time.

In the fall of 1986, the Congress debated bills which would have greatly increased the DoD resource commitment to drug interdiction. As finally passed, the Omnibus Drug Control Act of 1986 (HR 5484) authorized a number of additional equipment acquisitions by the military services on behalf of the drug interdiction program. The major items (discussed later in this section) were:

1. Four E-2 Hawkeye aircraft to be refurbished by the Navy for drug interdiction purposes ($138 million); two were to be provided to the Coast Guard and two to the Customs Service.
2. Seven radar aerostats ($99.5 million), to be loaned to agencies designated by the National Drug Enforcement Policy Board.
3. Eight Blackhawk helicopters ($40 million), to be loaned to agencies designated by the National Drug Enforcement Policy Board.
4. Installation by the DoD of 360-degree radar on Coast Guard long-range surveillance aircraft ($45 million).

Appropriations for these items have fallen short of authorization figures. It appears that only the first item has received the full appropriation. Money has been provided for only five of the seven aerostats ($71 million), and only $18 million has been provided for purchase of the additional Blackhawks. We have not been able to determine whether the radar installation funds have yet been appropriated.

The DoD Drug Task Force has also prepared estimates of expected expenditures on operating programs, as distinct from equipment procurement, in support of drug enforcement. The preliminary estimates from the Task Force are given in Table 4.1.

The estimates of operating program expenditures given in this table are significantly higher than those provided by other sources, such as those from OMB. They represent the result of a dedicated effort and

Table 4.1

PRELIMINARY TASK FORCE ESTIMATES OF DOD EXPENDITURES FOR DRUG INTERDICTION

(In $ millions)

Fiscal Year	Direct Operating Costs	Allocated Costs	DoD Equipment Costs Appropriated by Congress
1982	4.8	NA	NA
1983	9.7	NA	NA
1984	14.5	NA	NA
1985	54.8	NA	NA
1986	69.7	126.3	138.6
1987	72.7[a]	131.4[a]	314.0
1988	75.2	136.2	—

SOURCE: DoD Drug Enforcement Task Force.
NOTE: NA = not available.
[a]Inflated by OMB inflator index using 1986 costs.

may well include more information than was available to other estimators. Consequently, we accept these as the most authoritative estimates available.

The estimates show a very large increase in operating costs in fiscal year 1985 and a relatively modest increase in fiscal year 1986. Given rising political concern about DoD interdiction participation, our expectation was that 1986 should have seen a very substantial increase over 1985. Yet even in 1987, only equipment expenditures showed a large increase.

DoD INTERACTION WITH CIVILIAN LAW ENFORCEMENT

Interdiction remains primarily a civilian effort. The military services support certain aspects of the program but do not run any themselves. DoD assistance divides roughly into two categories: loans or transfers of equipment, ammunition, weapons, etc., and military operations, primarily training but also assistance in drug interdiction and training of pilots and other civilian specialists. We consider first the loan or transfer of military equipment, which is accomplished at different levels in a variety of planned and unplanned ways.

Loans of Equipment

There is no centralized mechanism for informing civilian officials about the resources the DoD has available or for initiating requests for these resources. Rather, there are varied sources of information and request channels. To date, the services have resisted giving the civilian agencies a "wish list" of what is available; they prefer that the law enforcement agencies state a need to which they can respond. The 1986 drug law requires, however, that the DoD provide a detailed list of equipment, support, and all forms of assistance that can be made available for drug interdiction, and the DoD Drug Task Force has compiled a draft version of this list.

At the present time, the DoD provides guidance and information, and further interactions come from both sides:

- When a law enforcement agency faces an emergency requiring equipment under time constraints, that agency may make a verbal request for the services known to have the capability to assist. This verbal request is later to be followed by a written formal request. The civilian official may go to a base commander in the region in which his agency is operating, to the NNBIS (National Narcotics Border Interdiction System) in the area, or to a service headquarters in Washington for a response to the emergency. The service or base commander will determine whether the support requested is available, and whether handing over the equipment would have an impact on the readiness of the unit affected. Typically, such requests relate to weapons or equipment needed for a specific operation, such as an FBI sting operation. They are checked out with the legal staff for possible infractions of the law before compliance.
- Formal requests for assistance can come directly to the services or to a base commander from an agency or through NNBIS. In these cases, the agency or NNBIS knows what is available where and goes to the source. Some of the requests may be what one Army colonel dubbed "show and tell": The requester explains the need, and the services tell him what military resources might be available to do the job.
- Some requests come directly to the DoD and are directed to the Assistant Secretary of Defense for Force Management and Personnel, of which the DoD Drug Task Force is a part. The latter determines which service is equipped to comply with the request and directs it to that service.
- The NNBIS formally processes requests for large amounts of equipment from civilian agencies and presents them to the DoD

at the quarterly meetings held in Washington. Such requests have a longer lead time than the three types described above.

Prior to the quarterly NNBIS meetings, the law enforcement agencies reach agreement among themselves on the equipment they need from the military. They consolidate these requests and present their plans and lists of needs at the meetings, which are attended by representatives of the civilian agencies, the services, and the DoD Drug Task Force. These requests include a range of items, from aircraft to binoculars. Conference participants iron out the requests on the basis of equipment availability, and the Task Force passes them on to the Joint Chiefs of Staff (JCS) and to the services that have jurisdiction over the specific items.

Military Operations in Support of Drug Interdiction

Planning and coordinating the second type of request—military training missions that assist in drug interdiction—require considerable time. These missions are planned by the services in consultation with drug enforcement officials and are presented for approval at the NNBIS quarterly meetings. Military missions that assist drug enforcement agencies must still, by statute, have training as their primary purpose.[1] The scheduling of routine training missions may take into account the needs of civilian law enforcement and accommodate these needs, but these needs are secondary to military training.

The services vary in their approaches to interdiction requests. The Navy has separate planning procedures for the Atlantic fleet and the Pacific fleet. In each area, the Navy receives requests from the Coast Guard and meets with Coast Guard representatives before the quarterly NNBIS meetings to work out compliance. At the meetings, the Navy outlines where and when its ships will be operating and holding training exercises that could benefit drug interdiction operations. The Coast Guard in turn determines what missions to cooperate in and what teams will accompany the ships. Together, they also confer about schedules for E-2 surveillance missions. The Navy works out the schedules and presents them at the NNBIS meetings.

The Coast Guard, the relevant interdiction agency, made little use of Navy vessels in the first year of the program, apparently because the Navy offered very limited flexibility in the use of its ships. The ships

[1]Civilian agencies may be required to reimburse the services for costs incurred in drug-related missions, compatible with maintenance of their military readiness, if these missions are not deemed to provide equivalent training services to the military. There have been very few such reimbursements.

could divert from their naval duties for only a limited distance or time. Consequently, the Coast Guard did not judge it useful to use many of these "steam days" to place a Coast Guard officer aboard a Navy vessel (the presence of a Coast Guard officer is necessary if the vessel is to have the legal authority to stop and search suspected smuggling boats).

The early problems revealed the difficulties of coordinating military and interdiction missions. Congress appropriated $15 million in fiscal year 1986 to train 100 five-member Tactical Law Enforcement Teams (TACLETs), to be placed aboard Navy vessels. "The Navy has offered 344 'ship steaming days' [in the first 8 months of 1986] to the Coast Guard, which has availed itself of only 91, in part because it has fully trained only 55 TACLET personnel . . . [but] because of the ebb and flow of Navy fleet operations and the short transit times through drug interdiction areas, all 500 of the designated TACLET personnel, even when trained, probably 'cannot be used productively aboard Navy ships'" (Morrisson, 1986, p. 2108, quoting a Coast Guard official).

The Coast Guard has also pointed out that its own training facilities are quite limited. Having to provide training to an additional 500 personnel within a year strains its capacity. Moreover, there was no guarantee that the appropriation would be continued beyond fiscal year 1986. That, together with concerns about the limited utility of Navy steaming patterns, reduced initial Coast Guard enthusiasm for the program. Since April 1987, however, it appears that the Coast Guard has been able to make more use of the Navy support program; in April alone, five smuggling vessels were seized by Coast Guard officers aboard Navy vessels. The Navy's decision to permit boarding of foreign or stateless vessels, with no more restrictions than those that would apply for a Coast Guard vessel making the boarding decision, apparently helped increase the utility of the program.

Military involvement has continued to be somewhat episodic, though coordination has been improved by the DoD Drug Task Force. For example, the DoD provided interagency voice privacy radio networks using DoD equipment and facilities during a 1985 blockade of the Colombian coast.[2]

The Air Force handles requests for support on a case-by-case basis, conferring with the agency requesting support and working through NNBIS. In addition, the Air Force designates approximately six

[2]These blockades were the aforementioned Hat Trick operations. Naval vessels and aircraft were used extensively for drug interdiction purposes for a period of several months. Hat Trick I was conducted in the fall of 1984 and lasted 60 days. Hat Trick II was a more ambitious effort, lasting from November 1985 to March 1986. RAND was not able to obtain information on the extent of military resources committed to these operations.

AWACS flights per month for drug interdiction and coordinates with Customs on how best to use the AWACS for drug interdiction, while at the same time satisfying the Air Force training mission. If this means changing the originally planned orbit of flight, the Air Force tries to accommodate Customs by doing so. The designated AWACS flights carry Customs officers aboard.

Aside from the designated AWACS flights, the Air Force considers all other AWACS flights as watch missions. If in the course of such flights they observe suspicious traffic, they report it to the law enforcement agencies in the area for further action. Undesignated flights do not carry law enforcement officials.

It is generally agreed that the AWACS flights have generated very little interdiction-relevant information. As of the end of 1985, AWACS had flown 1,308 hours in support of drug interdiction and had generated five drug seizures (U.S. Congress, 1986, p. 116). Given the estimated cost of an hour of AWACS time (roughly $10,000), this seems a very modest return on the expenditure.

Interviews with interdiction personnel suggested that there were two reasons for the lack of success of the AWACS missions: First, U.S.-based AWACS are flown largely for training purposes and the flights must be scheduled weeks in advance to meet the training needs of different personnel. Thus they cannot be flown at times when the interdiction agencies have information to indicate that the air is rich with targets, i.e., the flights cannot respond to tactical intelligence.

Second, the training is oriented to picking up a certain kind of target, generally faster and larger than drug-smuggling planes. Thus the AWACS planes miss many of the relevant targets. There is also anecdotal evidence of "flooding" of pursuit resources; an AWACS generates many low-probability targets and drains off the available pursuit resources early in its mission.

More success has been achieved with the less expensive Navy E-2, another sophisticated air surveillance plane. The schedules of the E-2 are more flexible and the targeting regimes more appropriate.

The Army conducts two training activities along the U.S.-Mexico border to assist in drug interdiction. These exercises are incidental to normal training cycles and are coordinated with the law enforcement agencies in the area. The first, Operation Groundhog, is an end-of-course test at the Army Intelligence Center at Fort Huachuca, Arizona, done in cooperation with the Border Patrol, near Yuma. For a four-day period trainees use ground surveillance radar to detect and track targets across the border. Information about targets detected is passed on to the Border Patrol for action.

Operation Hawkeye, also part of a training mission for students in Fort Huachuca, conducts missions along the Mexican border area during which selected target areas are imaged with the Mohawk's camera system. The mission is coordinated with the Patrol Division of the Customs Service, providing imagery and photography for the intelligence database. The Patrol Division works with the Army at Fort Huachuca to determine flight paths. If it needs emergency surveillance, Patrol may request the pilots at Fort Huachuca, who are making individual flights to gain flying hours, to check the specific areas and report their findings.

Some of the limitations in military interdiction support arise from legal prohibitions. For example, military officers do not have arrest authority. Legal staffs also must review all support, loans, transfers, etc., from the military services to civilian agencies. However, the overall problem is that interdiction is a secondary goal for the military units involved. This means that interdiction has to be fitted into the training and operations requirements of other missions. That fit is often difficult to achieve, though there are exceptions, such as Operation Groundhog mentioned above. The difficulty of meshing is perhaps shown most acutely by the highly publicized use of the very expensive AWACS equipment in drug interdiction along the southern border.

Does the system work well? When this question was asked of representatives of the services, they replied affirmatively, citing the quantity and variety of assistance given to drug interdiction by the military. Based on the number of refusals of requests by law enforcement agencies, it would appear that the system is working satisfactorily, in that very few requests from interdiction agencies to the military are turned down.

The GAO (1983, p. 76) reported 156 requests for military assistance between 1971 and 1981, of which 90 percent were approved. In 1984 the DoD received 9,831 requests for assistance and honored 9,819 of them, refusing just over 0.1 percent.[3] Undoubtedly, the bargaining and consultation process eliminated many requests before they became formalized. The military agree that they cannot tell the law enforcement agencies how to do their jobs. The agencies have to know what they need and how the services can help them when they request military assistance.

To better understand just how much the military services might add to the interdiction effort, we now consider in some detail the use of military air assets. We shall deal more briefly with military ship assets, since they have less distinctive capabilities in this mission.

[3]Hearings befo. House Committee on the Judiciary, "Military Cooperation with Civilian Law Enforcement," April 24, 1985, p. 124.

THE USE OF DoD AIR ASSETS TO COMBAT AIR SMUGGLING

In analyzing the use of DoD assets to combat air smuggling, it is helpful to consider the air interdiction process as having four phases: surveillance, identification, pursuit, and arrest. The surveillance phase includes the observation of an aircraft, typically by radar. The identification phase covers the process of deciding that the observed aircraft is likely to be a smuggler and should be pursued. The pursuit phase involves closing with the target and following it until it has entered the United States or made an airdrop to a vessel that is in, or about to enter, U.S. waters. The arrest phase involves getting Drug Law Enforcement (DLE) forces to the location of the smuggler with the drugs, closing with the smuggler, and making an arrest.

In keeping with this four-phase description, the probability that an air smuggler will be interdicted may be written as a product of four conditional probabilities:

1. That a smuggler will be "seen" by a surveillance device.
2. That the smuggler will then be identified as suspicious.
3. That he will then be pursued.
4. That he will then be caught.

The product of these conditional probabilities can be made no larger than the smallest of the four. Hence, no deployment of assets, the DoD's or anyone else's, can effectively increase the probability of interdiction unless there is adequate balance among the resources for all four phases. The following qualitative discussion addresses the four phases and the effect that DoD assets could have in increasing the conditional probability of success in each phase.

Surveillance

If a smuggler is attempting to enter the United States with illegal drugs in a vessel, vehicle, or aircraft, without clearing Customs at a port of entry, the DLE forces may become aware of the smuggling operation (1) accidentally,[4] (2) as a result of visual observation, (3) through intelligence, or (4) from noting suspicious radar tracks.

Of these, radar provides the only means of insuring reasonable levels of detection of air smugglers. The limitations of intelligence were reviewed in Section III; accidents are, of course, inherently chancy; and

[4]For example, drugs are often found on smugglers' planes that have crashed. Such crashes are not uncommon, as the planes often fly at very low altitudes to remote airstrips which do not have landing equipment.

anything that can be accomplished by visual sighting can be accomplished more efficiently by radar. Unfortunately, radar has serious shortcomings.

The existing radars are line-of-sight,[5] so the curvature of the horizon or intervening mountains on land limit the effective coverage that can be achieved with a radar installation.

If a target is illuminated with enough energy to provide a discernible return, the radar energy can be easily detected by receivers on the target. This is the technology used in the radar detectors sold to warn drivers of police radars. Another common device that uses this technology is the simple aircraft transponder. In normal use, it detects the illumination from a ground-based radar, flashes a light in the cockpit, and transmits a code that provides a stronger signal to the receiving radar. The transponder can be used as a radar detector if its transmitting circuitry is disabled.

In short, with modest expenditures a smuggler may be able to detect when he is being observed on radar, and when and where he is not. This reduces the element of surprise, allows the smuggler the option of detouring to another foreign country when he is illuminated by a radar he considers troublesome, and, in the case of fixed radars, enables him to map the areas with and without coverage.

A radar located at surface level and looking up has extensive coverage against large and high-flying airplanes. The physics of the situation are ideal: Anything in the air that generates a strong return signal is a potential target and should be displayed on the screen. The only parameter is the strength of the signal, which must be sufficient to ensure that the target will be displayed. The radar should be set so that the threshold signal is just below the point that radio noise and returns from moisture and particles in the atmosphere begin to cause confusion.

The disadvantage of such radars in observing smugglers is the line-of-sight limitation: Surface radars may be easily avoided by flying low at an adequate distance from the radar to ensure being "under" the radar's coverage.

The obvious foil to smugglers (or invading enemy aircraft) flying at low altitude is to put the radar up in the air (e.g., in a blimp or an aircraft) so that it can look down. The immediate problem with a "look-down" radar is that everywhere the radar "looks," it will see a return;

[5]Recent research has produced prototypes of low-frequency and over-the-horizon (OTH) radar that avoid the line-of-sight limitation. The obvious military applications of these technologies do not suggest that they will soon be useful for detecting small, slow aircraft beyond the line of sight. Therefore, we have not considered these or other potential assets that are currently in research or development stages.

hence there must be some way to discern targets from ground clutter. The most common method is to process the signals with filters that delete all returns that are not moving. Again, the difficulty is in setting the threshold.

When the radar platform is moving, it is especially difficult to distinguish between returns from stationary objects and those from slow-moving targets.[6] Typically, a minimum speed is set and all targets appearing to move faster than the minimum are displayed. If the minimum speed is picked to display aircraft, it will not display boats or cars. Military "look-down" radars for detecting aircraft are designed to be effective against fairly large and fast targets. A small aircraft suitable for smuggling a high-value drug such as cocaine may have a radar cross section substantially less than 5 square meters. Even the radar cross section of a medium-sized twin-engine aircraft will probably also be less than that.[7] In short, a "look-down" radar that is effective against aircraft will have limited effectiveness against boats or cars and trucks.

The airborne smuggler who wants to avoid radar detection can fly in such a way that he will be mistaken for legitimate traffic or can fly under the coverage of known fixed radar, which is perhaps easier. The locations of fixed radars are known. Much of the Mexico-U.S. land border is mountainous, and the areas without fixed coverage can easily be found. Most mountain ranges, including those on the border, run north and south. Flying north through the valleys, even at night, at an altitude of 500 to 1,000 feet (assuming knowledge of the terrain and a minimum of commercially available equipment such as Loran and a radar altimeter) would be fairly easy.

Unique Capabilities of Military Radars. Existing fixed-base radars are inadequate for surveillance against drug smugglers, since most of the U.S.-Mexico border can be penetrated at low altitude. With the exception of southern Florida, most of the Gulf Coast could probably also be penetrated at low altitude without detection.

Radar-carrying aerostats could be effective against low-flying aircraft along much of the U.S.-Mexico land border, little of which is currently protected against aircraft with small (5 square meters) radar

[6]On complex, integrated radar systems, the problem of the moving platform is solved by using inputs from an inertial navigation system that allows the radar signal processor to correct for its own motion in the process of determining which returns are moving targets.

[7]Although the technology is not static, in this study we consider only existing and currently available hardware. In the future, smugglers could avail themselves of the more primitive aspects of stealth technology, including composite airframes and radar absorbing paints. The military, of course, faces an even greater stealth threat and must develop improved radars that could then be available for the DLE.

cross-section flying at 500 feet. Aerostats could increase the proportion of the border that has radar coverage against small, low targets; but if fewer than eight aerostats are deployed, it would probably still be possible to avoid radar coverage while flying over the border in a small aircraft.

Unique requirements of the military mission have led to the development of large, powerful airborne radars. The most effective radars used by Customs are F-15 and F-16 radars on loan from the Air Force. Even more effective for the surveillance role are the command-and-control radars available on the Navy E-2 and the Air Force E-3 (AWACS). These multimission radars are expensive to operate and in high demand, but they have exceptionally good range, target identification ability, and mobility, making them among the most valuable military assets available for the DLE to use against air smuggling.

The E-2 and E-3 aircraft carry a staggering amount of computer capability to process the radar signals from many simultaneously tracked targets. This capability, which is underutilized in DLE work, also makes the E-2 and E-3 aircraft very important to the primary mission of the armed services, i.e., military readiness and deterrence.

The E-3 is a Boeing C-135 (B-707) airframe with a large horizontal radar dish mounted dorsally. According to *Jane's All the World's Aircraft*, the radar range is about 200 nautical miles against low-flying targets and the aircraft has about six hours' endurance on station 870 nautical miles from base. The E-3 has been used effectively both with and without Customs agents on board to facilitate identification. It has several radar screens on board, one or more of which can be manned by Customs officers.

Tinker Air Force Base, near Oklahoma City, is the training base for the E-3. The proximity of Tinker to the southern and southwestern U.S. border has been helpful in using E-3 training sorties for drug-smuggling surveillance.

The Navy E-2 Grumman Hawkeye is a twin turboprop with a large, horizontal radar dish, also mounted dorsally. The E-2 is much smaller than the E-3 and is capable of carrier operations. However, it does not have extra radar screens and has little room to carry Customs officers on board.

Customs agents in the Southeast have reported that the E-2 has been very helpful, but the E-3 less so. Agents in the Southwest say exactly the opposite. The disparity is probably explained by the location of the training bases. The E-2 crews train out of Norfolk, Virginia, and on occasion deploy south to Florida. In the Southwest, an E-2 sortie that is available to the Customs Air Branch is typically a flight from Miramar Air Station near San Diego and is likely to have

very little endurance on station in the area where it is needed. The E-3s have much longer range and are better suited for carrying a Customs officer, so the Air Branch in the Southwest finds the E-3s very helpful.

The radar in the Navy S-3 (whose primary mission is antisubmarine warfare) can detect small surface vessels. Other assets developed for military aircraft, such as infrared detection devices (usually referred to as forward-looking infrared, or FLIR), have been helpful in the pursuit and detection phases of the interdiction process.

Customs has had good luck retrofitting these radars and FLIR to their aircraft. The radars were designed as offensive equipment for F-15s and F-16s flown in air-to-air combat and, as such, they are very good at detecting other aircraft. Although the F-15 radar is more powerful and seemingly better suited to drug interdiction, it is also much bigger and may require more maintenance. Both radars have been very useful in improving the ability of Customs aircraft to fly radar patrols and seek out suspicious targets.

Aerostats. Three aerostats carrying "look-down" radars are in operation in the Southeast. One, belonging to Customs, is located at Cudjoe Key, near the west end of the Florida keys. A second Customs aerostat is located at Cape Canaveral. The third is an Air Force aerostat with a Cariball radar, located at Grand Bahama Island. The Customs radars are reportedly not very effective for detecting airplanes, and the Cariball radar is not very effective for detecting boats.

Congress has funded six additional aerostats for the Air Force, all to be devoted to drug law enforcement. One of these will be deployed in the Bahamas, and the other five are earmarked for the Southwest. The first of the aerostats for the Mexico-U.S. border will be under construction shortly at Fort Huachuca.

The effectiveness of aerostats along the southwest border is conjectural. Comprehensive radar coverage will be much harder to attain in the Southwest than in southern Florida, because of the rugged terrain near the border. In addition, the weather can be more severe there than in southern Florida. During thunderstorms and high winds, the aerostat must be reeled in, which takes about 20 minutes. Fortunately, the kind of weather in which the aerostat must be reeled in makes air smuggling along the rugged southwest border very unpleasant, if not downright dangerous.

The Florida smuggler who must make a substantial overwater flight before his landfall may find the aerostat a bigger obstacle than his counterpart who takes off from a remote field in northern Mexico: The Mexican pilot can wait until the aerostat is down for maintenance, or down because of forecast high winds.

Identification

Mixed assessments have been made of the ability of DoD radar personnel to identify suspicious smuggling targets for tracking. The training to identify a jet fighter-bomber enroute to a target and vector an air-to-air fighter against it provides less-than-perfect preparation for identifying small, slow-moving targets that might be smuggling drugs.

The expertise and experience required here lie primarily within the Customs Air Branch. Being able to put Customs officers on E-3s has been an important help. It appears that in the Southeast, the profile of a suspicious aircraft can be adequately described to radar operators in the E-3s to make these operators useful observers.

The short tours of duty that are common in the DoD increase the problem of training military personnel to seek out and identify air smugglers. There is very little carryover from this training to the intended mission of the AWACS.

Pursuit

The flexibility and unpredictability of the airborne smuggler makes interdiction difficult. Depending on his point of departure and fuel capacity, he may be headed for an airborne drop to a boat off the coast; he may penetrate well into the central United States; or he may be planning to land or make an airdrop anywhere in between. Adding to the difficulty, pursuit must be done covertly to avoid alarming the smuggler, who often has the option of diverting to a foreign country or jettisoning his cargo.

Effectively pursuing airborne smugglers requires aircraft that are airborne or on alert status in an area that is close to the surveillance assets. In the case of fixed radars, dedicated aircraft may have to be on alert at a base or bases near the border and the surveillance radar.

Ideally, the aircraft used for pursuit should have a broad speed range: Cruise speeds for general aviation aircraft vary from about 90 to 480 knots. Most military fighter aircraft will exceed the 450- to 470-knot cruise of a Lear Jet or Cessna Citation. It is the low speeds of many civilian aircraft that cause a problem.

A typical four-seat civilian aircraft may cruise at as little as 105 knots. The medium twins that seem to be the most common choice for smuggling may cruise at 140 to 170 knots. Typical approach speed for a military OV-10 is 105 knots; that of an A-10 is 120 knots; and that of fighter aircraft such as the F-4 is about 150 knots. Approach speeds represent the low end of the speed spectrum where the pilot can maintain adequate control. The disadvantage of flying fighter aircraft at

these speeds, or at speeds close to the approach speed, is that they consume fuel at a rate that severely limits their endurance.

A flight of two or three fighter aircraft could be used in the pursuit role. One aircraft could circle to get into a position well behind the target while the other was tracking the target. After the circling aircraft was well behind the target and had acquired it on its radar, the leading aircraft could begin the circle maneuver. If the intended landing place of the smuggling aircraft is unknown or the pursuit aircraft are not based near the surveillance radar that spotted the target, tanker support may be necessary. Covert pursuit of small aircraft in this manner requires that the pursuing aircraft have a good "look-down" radar. This may limit the available aircraft to the later models of the F-4, F-15, and F-16, or the Navy's F-14 and F-18.

Although a capable down-looking radar may be important for pursuit by fast military planes, FLIR devices can be an important asset to planes that are slow enough to close with smuggling aircraft from behind without flying by the smuggler and alarming him. The FLIR can be used to identify the smuggler's aircraft, obtain his registration numbers, and cross-check that identification with computerized files.

Arrest

The flexibility of the smuggler also makes the arrest phase difficult: He may use remote airstrips and must be captured before his cargo has been offloaded and the smugglers have dispersed. Because of the Posse Comitatus limitations, the aircraft used in the arrest phase must carry a sufficient civilian DLE force—at least three or four personnel, and preferably more.

In the unlikely event that a smuggler is expected to land at a civilian airport, most military aircraft capable of carrying passengers could serve in the arrest phase. But unless the smuggler is flying a heavy twin or business jet, he is more likely to land at a remote strip. In that case, the choice of suitable aircraft for the arrest phase may be limited to helicopters. A smuggler landing at a remote strip could close the strip to other fixed-wing aircraft by parking a plane or a car on it.

Military assault helicopters have been useful in the arrest role, especially the Army's Blackhawk, which can carry 11 troops in addition to a crew of three and has a maximum speed of about 160 knots (*Jane's All the World's Aircraft*). A fast helicopter improves the chances of arriving at the landing site in time to make a successful arrest.

If the DLE forces are mounting a special effort with surveillance radars and pursuit planes on alert, military helicopters could be

deployed in small numbers and kept on alert at almost any military base without attracting attention.

SUMMARY

Military aircraft have, and will continue to have, a role in the program to interdict air smugglers. Unfortunately, there is considerable demand for the aircraft that can be most useful in the drug interdiction effort, the E-3 and the E-2. Both of these aircraft are almost always in demand somewhere in the world to ensure the readiness of U.S. or allied forces, and their importance in wartime demands a cadre of well-trained operators. Balancing these needs with the need to combat air smuggling will continue to be difficult.

These aircraft could mount an intensive air surveillance effort anywhere along the southern border of the United States with little preparation. Although the use of an active radar and the requirements of scheduling and flying one or more E-3 sorties may keep such an effort from being a completely covert operation, it can be done much more discreetly than could any other similarly effective surveillance efforts. Temporary and flexible surveillance is needed to keep the smuggler off guard. For these reasons, the AWACS aircraft are potentially very important.

It seems appropriate for training sorties to continue to be allocated to drug interdiction. It is also desirable that some limited number of requests be negotiated between the DLE (Customs, and possibly the Coast Guard) and the Air Force and Navy to allow the services to support requests for near-term surveillance sorties at specified locations and times.

To be effective, such surveillance sorties may require making other aircraft available for the pursuit and arrest phases. We believe that the Customs Air Branch will usually have enough suitable aircraft to cover the pursuit phase. If they are necessary and available, Marine OV-10s with FLIR have a demonstrated pursuit capability that can supplement the Customs pursuit aircraft.

Blackhawk helicopters, or other helicopters with similar capability, can be very important in the arrest phase. With long-range bladder tanks, the Blackhawks have a capability for limited-range deployment, but this could be the weak link in assembling a flexible "interdiction task force."

Although this section has concentrated on the use of military aircraft, the military has many other assets they are making available. The services may not have all the communication capability they

desire, but they are well ahead of the DLE in their communications facilities. Although the military has loaned considerable communications gear to the DLE, to the best of our knowledge, the DLE has not been given access to the satellite communications channels and the associated equipment that could greatly improve their communication and coordination.

Because it is our understanding that the effectiveness of Navy surface assets is not very much greater than that of the Coast Guard and Customs Marine Division assets, we shall not present a similarly detailed discussion of military assets in the maritime interdiction effort. A battleship will not do much better than a 110-foot cutter in patroling and pursuing drug-smuggling vessels. The Navy, because of the pattern of deployment of its ships in the oceans of the world, does not maintain a large number of ships in the Caribbean or along other parts of the major importation routes. Consequently, Naval assets are not likely to greatly augment the efforts of the maritime interdiction agencies.

Our assessment of the impact of additional air and naval resources on drug smuggling is presented in Sections V, VI, and VII. However, the descriptive material in this section indicates some of the limitations on the ability of the military to increase the risks to smugglers from interdiction.

V. INTERDICTION EXPENDITURES AND ACCOMPLISHMENTS

This section describes the recent history of the overall interdiction program. It begins with a brief outline of the growth in program expenditures and then describes the visible accomplishments of the program, seizures and arrests. We next attempt to develop more refined measures of the impact of these accomplishments on the costs of smuggling. These measures suggest that the great increase in interdiction expenditures has not led to comparable growth in the impact of interdiction on cocaine importation; the results for marijuana are less clear. In conclusion, we present some preliminary analysis of the reasons for the declining measured effectiveness of cocaine interdiction.

EXPENDITURES

Interdiction expenditures have grown very substantially in the past five years. The OTA estimates that total expenditures were $372 million in fiscal year 1981 and had risen to $762 million by fiscal year 1986 (see Table 5.1). Both figures include estimates of expenditures on port-of-entry drug enforcement by the Customs Service, which is distinct from, though related to, other interdiction activity. If the port-of-entry expenditures are subtracted from the total, the rate of increase is even higher, from $263 million in 1981 to $605 million in 1986 (130 percent).[1]

Coast Guard expenditures were about 45 percent of the larger totals in both years. The OTA estimated the DoD's contribution in support of the interdiction program to be approximately $40 million in 1986, compared with less than $1 million in 198.. As mentioned earlier, these figures are lower than the more authoritative estimates provided by the Task Force.

No breakdown of expenditures by drug exists. Given the nature of the interdiction activity (heavily patrol-oriented), however, it is not clear that such a breakdown would be meaningful. Most of the Coast Guard's expenditures should probably be allocated to marijuana interdiction, but the other expenditures include significant elements of both drugs.

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[1]When we adjusted for inflation, using the OMB deflator, the increase was 85 percent.

Table 5.1

BUDGET OUTLAYS FOR DRUG INTERDICTION PROGRAMS, FISCAL YEARS 1981–87

(In $ millions)

Agency	1981	1982	1983	1984	1985	1986	1987
Interdiction Agency Outlays							
U.S. Coast Guard	175	195	280	305	325	350	375
Customs-Marine	13	13	12	26	47	33	34
Customs-Air	27	18	26	65	67	69	72
Customs-Port of Entry	109	116	97	119	153	157	128
Customs-Support	13	15	31	39	45	52	56
Subtotal	337	357	446	554	637	661	665
Interdiction Support by Other Agencies							
DoD	—	5	10	15	40	40	45
DEA	33	34	41	48	49	57	62
Other agencies (FAA, Border Patrol)	2	3	3	3	3	4	5
Subtotal	35	42	54	66	92	101	112
TOTAL	372	399	500	620	729	762	777

NOTE: Does not include FY86 appropriations of $35 million for Air Force C-130 gunships. Coast Guard figures do not include major acquisitions (cutters, aircraft, etc.). Interdiction support figures are very rough estimates. DoD figures do not include operating costs for training missions. DEA figures assume that 15 percent of DEA law enforcement expenditures are for interdiction support.

SOURCE: Office of Technology Assessment, 1986.

ACCOMPLISHMENTS: FIRST ESTIMATES

The measured results of these increased expenditures show mixed trends. The quantities of cocaine and marijuana seized are shown in Table 5.2. Cocaine seizures, mostly by the Customs Service, have risen dramatically, particularly in 1984 and 1985. Marijuana seizures have declined by almost 50 percent to 2,000 metric tons, but, as discussed below, that may reflect a major decline in the flow of marijuana imports along interdiction-prone routes.

As noted earlier, the figures on seizures are subject to major uncertainties. In 1983, the GAO found evidence of considerable double counting, with some seizures being counted by more than one agency. The GAO estimated that the total for marijuana in 1981 was overstated by about one-half, based on a sample of seizures they traced through the major agencies. In 1986, the OTA found that:

Table 5.2

CUSTOMS AND COAST GUARD DRUG INTERDICTION EFFORT: QUANTITY OF DRUGS SEIZED, FISCAL YEARS 1981–86

(In metric tons)

Fiscal Year	Customs Service		Coast Guard		Total	
	Cocaine	Marijuana	Cocaine	Marijuana	Cocaine	Marijuana
1981	1.70	2317.79	0.00	1,687.82	1.70	4,005.61
1982	5.06	1795.73	0.02	1,630.84	5.08	3,426.57
1983	8.89	1239.67	0.02	1,043.19	8.92	2,282.86
1984	12.47	1480.63	0.88	1,296.16	13.35	2,776.78
1985	22.36	1083.42	2.67	885.20	25.03	1,968.62
1986	23.82	1002.92	3.40	834.92	27.22	1,837.84

SOURCE: Calculated from National Drug Enforcement Policy Board, *Federal Drug Enforcement Progress Report 1984-1985*, March 1986, p. 139, and *Federal Drug Enforcement Progress Report 1986*, April 1987.

NOTE: Some seizures may be reported by both the Customs Service and the Coast Guard, which creates an upward bias in our estimate of total seizures.

> Seizure data provided separately by the Coast Guard and Customs Service were mutually inconsistent. For example, together the Coast Guard and the Customs Service claim credit for an amount (by weight) of marijuana seizures totaling almost twice the total marijuana seizures from non-commercial vessels reported by EPIC in 1984. The agencies do not reconcile these differences and EPIC's reports do not identify the agency responsible for seizures within each mode of transport.

We shall make no further comment on the quality of seizure data. For most purposes, adjustment is not necessary, since we are concerned only with growth in seizures. We have no reason to believe that the extent of double counting has altered over [illegible] past five years. Moreover, we have no alternative estimates [illegible]blem is well understood, and procedures are being implemented to reduce the incidence of double counting (PCOC, 1986, p. 365).

The distribution of seizures by mode of transportation and entry point is also important for our analysis (see Table 5.3). Of particular interest is the proportion of cocaine seizures at port of entry (mostly in commercial airline cargo). While it is impossible to extrapolate from the distribution of seizures across modes to the distribution of smuggling across modes, it seems likely that a very significant share of the

Table 5.3

DISTRIBUTION OF COCAINE AND MARIJUANA SEIZURES, BY MODE, FISCAL YEARS 1981–85

(Percent of total weight seized)

Mode	1981	1982	1983	1984	1985
		Cocaine			
General aviation	75	53	66	62	56
Commercial airline	22	36	12	18	10
Private vessel	1	2	16	11	28
Commercial vessel	1	8	4	8	4
Land	1	1	2	1	2
		Marijuana			
General aviation	8	6	7	7	4
Commercial airline	1	0.5	1	1	1
Private vessel	88	91	86	84	87
Commercial vessel	2	1	4	3	3
Land	1	1.5	2	5	5

SOURCES: EPIC, *Drug Movement Indicators/Profile*, 1981 and 1982; National Narcotics Intelligence Consumers Committee, *Narcotics Intelligence Report*, 1983 and 1984; DEA, *Worldwide Drug Assessment*, June 1986.

cocaine in this country enters through ports of entry. Table 5.4 provides further detail for cocaine.[2]

As a measure of interdiction effectiveness the numbers of arrests and imprisonments are as relevant as the numbers of drug seizures. Data on arrests and imprisonment are much more sparse (though probably more accurate) than data on seizures. However, the Coast Guard has statistics on the numbers of persons it arrests (Table 5.5), and the Coast Guard Seventh District (headquartered in Miami), which accounts for the vast bulk of the agency's drug interdiction effort, has also developed figures on the percentage of those arrested who are prosecuted and convicted. These figures are presented in Table 5.6; they show no indication of growth in the numbers of prosecutions.

The length of prison sentences received by those convicted has previously been a matter of some uncertainty. The Coast Guard, in response to the 1983 GAO Report, suggested assuming the average sentence received by drug offenders in the Southern District of Florida, 1.9 years in 1981.

[2]There are significant discrepancies in the data in the two tables. Table 5.4 reports seizures of 5,018 kilograms of cocaine on commercial airline flights, clearly far more than the 10 percent of cocaine seizures shown in Table 5.3 as originating in commercial airline cargo.

Table 5.4

U.S. INTERDICTION SEIZURES OF COCAINE, BY MODE AND SIZE OF SEIZURE, FISCAL YEAR 1985

	Size of Seizure (kg)				
Mode	1–9	10–99	100+	Total No.	Total Wt. (kg)
General aviation	4	9	28	41	9,696
Commercial airline	195	25	9	229	5,018
Land border	30	3	3	36	721
Maritime	27	26	20	73	8,008
Total number	256	63	60	379	—
Total weight	646	2,332	20,485	—	23,463

SOURCE: U.S. Drug Enforcement Agency, submitted in testimony before the Government Information, Justice, and Agriculture Subcommittee of the House Committee Hearings on Government Initiatives in Drug Interdiction (Part 1), 1986, p. 608.

Table 5.5

NUMBERS OF COAST GUARD ARRESTS, FISCAL YEARS 1981–85

Year	No. of Arrests
1981	1,010
1982	1,128
1983	780
1984	1,149
1985	831

SOURCE: U.S. Coast Guard.
NOTE: Includes arrests by other agencies assisted by the Coast Guard.

Table 5.6

COAST GUARD SEVENTH DISTRICT DRUG PROSECUTION PROFILE, 1982–85

Item	1982	1983	1984	1985
Federal Prosecutions				
No. of arrests	780	731	937	660
No. of prosecutions	602	576	751	545
(Percent of arrestees prosecuted)[a]	(77.2)	(78.8)	(80.2)	(82.6)
No. tried/pleaded in federal court	592	521	560	198
(Percent of defendants prosecuted)	(98.3)	(90.4)	(74.6)	(36.3)[b]
No. of federal convictions	527	444	508	186
(Percent of defendants convicted)	(89.0)	(85.2)	(90.7)	(93.9)
(Percent of arrestees convicted)	(67.6)	(60.7)	(54.2)	(28.2)[b]
No. of State and Foreign Government Prosecutions[c]				
State	11	2	7	17
Foreign	0	22	17	19

SOURCE: U.S. Coast Guard, Seventh District, January 1986.

[a]Some individuals were prosecuted by state and foreign governments, as indicated below.

[b]Data available as of December 31, 1985; most cases were still pending at that time.

[c]No disposition information was available on these cases.

Many observers believe, however, that the sentences received by crew members of foreign nationality, at least for marijuana seizures, may have a very much lower average length. On the other hand, data provided by the Coast Guard on sentences received by its drug arrestees in 1986 show that long sentences are in fact given. The average sentence for that year was 4.6 years, almost identical to the figure for federal drug sentences generally. Very few of those convicted did not receive prison sentences. The relevant data are presented in Table 5.7.

Though we do not know how sentence length has changed for smuggling arrestees, we know that the average term for federal drug offenders increased substantially over the period, from 46 months in 1981 to 56 months in 1985. Also, in recent years, prosecutors have

Table 5.7

DISPOSITION OF COAST GUARD SEVENTH DISTRICT ARRESTS, 1986

Item	Value
Total number of cases[a]	101
Total number of defendents	454
Number found guilty	414
(Percent found guilty)	(90.5)
Average sentence, months	55.5

SOURCE: U.S. Coast Guard.

[a]All federal prosecutions concluded in 1986, arising from arrests by the Coast Guard Seventh District.

obtained sentences of probation, which permit expedited incarceration if the individual is caught on a similar charge later.

Regarding non-U.S. nationals, immediate deportation is no longer a practice of law enforcement officials. Coast Guard lawyers state that the prosecution of an alien can follow one of two scenarios, depending on the individual's country of origin. Colombia has given the Coast Guard permission to board and search vessels flying the Colombian flag. This permission has been granted on the condition that any Colombians found smuggling be deported back to that country for prosecution under Colombian law.[3] Aliens from countries that have not negotiated specific procedures regarding arrest and prosecution are brought to trial under U.S. law. If convicted, they are deported to their country of origin upon release from the correctional institution.

No comparable figures on arrests and prosecutions were available from the Customs Service. Total arrest figures have been published (National Drug Enforcement Policy Board, 1987, p. 80), and they appear to be dominated by inspectors' arrests at ports of entry, which involve very small-scale smuggling. The only available data on the Customs program outside of ports of entry give the number of pilots and others caught by the Customs Air Branch. Those figures, given in Table 5.8, show that the number has fluctuated substantially over the past five years. The number of pilots arrested is quite modest, averaging only 53 per annum over the five-year period, and has been declining during that time.

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[3]Only four ships of the 337 that the Coast Guard seized in 1985 were flying the Colombian flag; 139 flew the U.S. flag.

Table 5.8

NUMBERS OF ARRESTS BY U.S. CUSTOMS SERVICE AIR BRANCH, FISCAL YEARS 1982–86

Arresting Officers	1982	1983	1984	1985	1986[a]
Pilots	78	60	49	48	28
Others	113	277	409	263	141
Total arrests	191	337	458	311	169

SOURCE: U.S. Customs Service.
[a]Through August 1986.

ACCOMPLISHMENTS: REFINING THE MEASURES

Seizures

The volume of seizures is a very crude measure of interdiction efficacy. Seizures are effective not because of the quantity of drugs they remove from the market, but because they impose a cost on smugglers. An improved measure of seizure impact, then, is the replacement cost of drugs to smugglers.

Prior analyses (e.g., Systems Research Corporation, 1985) have valued seizures at retail prices, but this greatly overstates the cost imposed on the drug distribution system. Retail prices are very much greater than import prices. The smuggler does not have to pay retail prices to replace the lost drugs and does not forgo sales at retail prices as a result of the loss. For cocaine, the markup from import to retail is about tenfold; for marijuana, the markup is about fourfold.

The Coast Guard regularly reports the total value of its seizures. In fiscal year 1982, it reported $1.6 billion in seizures of cocaine, hashish, marijuana, and other dangerous drugs. The implied value of the marijuana seized was approximately $1.45 billion, which represents a price of $400 per pound. To derive this figure, we used upper price bounds for cocaine, hashish, and dangerous drugs and subtracted them from the total seizure value. Since the vast majority of Coast Guard seizures are of marijuana, changes in this assumption do little to alter the estimated marijuana value. If the import-level price had been used, the value of marijuana seizures would have been only about half that reported.

To correctly calculate replacement cost, we need a measure of the replacement cost of a kilo of cocaine or marijuana seized prior to entry into the United States. Neither export price nor import price is perfect. The export price fails to include the costs incurred after the

purchase of the drugs, such as hiring agents and buying or leasing transport equipment, so export price will be below the replacement cost. On the other hand, the import cost includes the pure profit earned from successful risk-taking and is thus too high. Given the lack of data on the profit margins at importation, we can only say that the replacement cost falls between the export price and the import price. We suggest as an interim measure the arithmetic average of the two prices.

The little available data on the export and import prices for these drugs during 1981 to 1986 indicate that seizure-related costs rise less than seizure quantities. As shown in Table 5.9, the simple seizure total for cocaine in 1985 rose to almost 14 times the amount seized in 1981, compared with a replacement-cost-weighted change approximately 9 times larger. For marijuana, the decline in total amount seized in 1985 was approximately one-half that seized in 1981. The replacement-cost-weighted level of marijuana seizures in 1985 was only one-third that in 1981.

The difference between the value and quantity series reflects the substantial declines in export and import prices for cocaine over the period (see Table 5.13, below). The declines were different for the two price series, so three different measures of replacement cost were used in Table 5.9: export prices, import prices, and the arithmetic average of the two. Since both export and import prices declined, the estimated replacement cost rose less than the unweighted seizure rate in all cases. Adjusting for general inflation over the period, the growth is even further reduced; for cocaine, the increase is 730 percent (only 60 percent of the weight increase), while for marijuana, the decline is almost 69 percent (compared with a weight decline of 51 percent).

The low quality of the price data (indeed, the lack of export prices for 1981 and 1982), together with the very rough imputation of the replacement cost from the two price series, makes these estimates very approximate. Our primary intention here is simply to suggest that evaluation of the impact of seizures is sensitive to choice of the correct measure of replacement cost. If the bulk of the difference between import and export prices is profits (return to risk-taking, monopoly rents, etc.), then the replacement cost may be close to export price and the impact of seizures may in fact be very modest.[4]

[4]We should also note that the series used for import prices certainly overstates those prices, though not necessarily their rates of change over time. The figures used for cocaine are the official estimates of the wholesale price of cocaine at the kilogram level. As shown in Appendix B, the price for transactions at the 10- to 100-kilogram level, which is closer to the actual import price, is about 20 percent less than that for transactions of between 1 and 10 kilos, which provide most of the data for the price series used here.

Table 5.9

COCAINE AND MARIJUANA SEIZURES, WEIGHTED BY CHANGING PRICE LEVELS, 1981–85

Item	1981	1982	1983	1984	1985	% Change, 1981–85
			Cocaine			
Total seized (metric tons)[a]	1.70	5.08	8.92	13.35	25.03	1,373
Thousands of dollars seized, weighted by price estimates[b]						
Import prices	102,000	304,545	445,818	600,721	1,001,306	882
Export prices	15,470	46,189	81,139	68,749	156,454	911
Avg. of ex-im prices	58,735	175,367	263,478	334,735	578,880	886
Avg. in constant dollars	64,473	180,791	263,478	321,552	536,000	731
			Marijuana			
Total seized (thousands of pounds)[a]	8,812	7,538	5,022	6,109	4,331	−51
Thousands of dollars seized, weighted by price estimates[b]						
Import prices	5,287,407	4,523,076	2,385,591	3,054,462	1,948,931	[illegible]
Export prices	127,779	109,308	72,823	76,362	49,806	−61
Avg. of ex-im prices	2,707,593	2,316,192	1,229,207	1,565,412	999,368	−63
Avg. in constant dollars	2,972,111	2,387,827	1,229,207	1,503,758	925,341	−69

SOURCE: Calculated from Tables 5.2 and 5.13.
[a]Figures for the total amount seized are from Table 5.2.
[b]Price estimates are from Table 5.13. Average of import-export prices represents the simple mean of the two figures for each year. Export prices were not available for 1981 and 1982; as a result, 1983 export prices were substituted in the calculations. Constant dollar estimates represent quantity seized, weighted by the deflated average of the export and import prices, using 1983 as a base year.

These figures on seizures should be evaluated against the scale of the drug industry, in terms of the volume of drugs smuggled and the value of sales. Estimates of these quantities are notoriously weak.

Table 5.10 presents the official estimates of quantities of cocaine and marijuana imported in each year between 1980 and 1985. Documentation of the basis for these estimates is not available, but discussions with those involved in the estimation process lead us to conclude that the error bands around these estimates are very wide. For example, there is no sample-based estimate of how much cocaine is typically used in a single session by users of different intensity; the quantity has

Table 5.10

MINIMUM AND MAXIMUM OFFICIAL ESTIMATES OF COCAINE AND MARIJUANA IMPORTS TO THE UNITED STATES, 1981–85

(In metric tons)

Drug	1981	1982	1983	1984	1985
Cocaine					
Minimum	38	50	75	110	111
Maximum	68	75	97	178	153
Marijuana					
Minimum	8,700	10,340	11,100	9,700	9,447
Maximum	12,700	12,090	13,500	14,350	12,228

SOURCES: National Narcotics Intelligence Consumers Committee, *Narcotics Intelligence Report,* 1983 and 1984; DEA, *Worldwide Assessment,* June 1986.

probably changed over time as a result of the declining retail price of cocaine and the spread of new modes of administration. Similarly, no basis exists for current estimates of the total domestic production of marijuana, a critical element in determining current marijuana imports; the estimate appears to be a residual which balances estimated consumption and estimated imports.

Some evidence of the uncertainty of official estimates was provided in June 1987 when the NNICC released a new report covering 1985 and 1986, which included two sets of estimates for marijuana. One was labeled "consumption" and the other "marijuana available for use in the U.S." The second set was estimated as total production minus all seizures (coastal, border, and internal) and losses, defined as "marijuana lost because of abandoned shipments, undistributed stockpiles, and inefficient handling and transport" (NNICC, 1987, p. 16). As thus defined, this appears to be very close to an estimate of consumption, unless domestic stocks vary greatly from year to year.

The first series was very much lower than the second and included a downward revision of the estimates for 1982. The second appeared to represent a continuation of the prior series. The differences for 1985 were striking: "Consumption" was estimated at 4,693.9 metric tons, while the net marijuana available was 6,400 to 8,300 metric tons. The estimated proportion of the marijuana that is produced domestically, 19 percent, was also much higher; the prior NNICC report had estimated 14 percent.

For cocaine, the 1985 consumption estimate was 72.3 metric tons, compared with an NNICC estimate for 1984 consumption of 110 to 178 metric tons. No estimate of "cocaine available for use in the U.S." was provided, but the report presented estimates of cocaine production in the source countries. For 1985, it was 252 to 273 metric tons. Given that the United States is usually believed to be by far the largest market for cocaine, this is scarcely consistent with a consumption estimate of 72.3 metric tons.

The new consumption estimates appear to be based on the national household survey carried out every two or three years by the National Institute on Drug Abuse. This survey provides the most authoritative data on use rates but is weak on frequency of use and gives no data on amounts used per session. No information was provided about how the household survey data were used to develop the estimates of total quantity consumed. Other efforts to use the household survey data, in conjunction with the High School Senior Survey data, have produced estimates of marijuana consumption in line with the revised NNICC consumption estimates (see Kleiman, 1985; and Reuter, 1984).

The only rigorous documented estimate of cocaine consumption (Carlson et al., 1983) produced a very much lower estimate for 1981 than did the NNICC for that year, 7.8 metric tons as compared with 31.2 metric tons (since revised upward to a minimum of 38 tons). This difference was the result of disagreements about the distribution of intensity of use among users, the number of use sessions per week, and the purity of cocaine at the retail level.

The dispute concerns fairly old data, and the values for all relevant variables are likely to have changed very substantially. We have no basis for preparing any alternative cocaine estimate, and we report the above only to suggest that there may be some upward bias in the official estimates of total quantity consumed. That in turn imparts a downward bias in estimates of interdiction seizure rates. We shall use the unrevised official estimates, since they provide at least a consistent series, through the rest of the report, referring to such figures simply as the official estimates.

Estimates of interdiction rates, based on the official estimates of total imports, are presented in Table 5.11. It is unlikely that interdiction rates for marijuana over the last five years have been higher than 40 percent or lower than 10 percent. Statements about trends in the interdiction rate for marijuana are also very difficult to make because of uncertainty about changes in the share that is domestically produced, but the rate appears to have declined.

It is highly probable that the interdiction rate for cocaine has risen sharply in the past five years. The rate may have been as low as 2

Table 5.11

INTERDICTION SEIZURES AS A FRACTION OF OFFICIAL ESTIMATES OF IMPORTS

Drug	1981	1982	1983	1984	1985
Cocaine					
Maximum	0.04	0.10	0.12	0.12	0.23
Minimum	0.02	0.07	0.09	0.07	0.16
Marijuana					
Maximum	0.46	0.33	0.21	0.29	0.21
Minimum	0.32	0.28	0.17	0.19	0.16

SOURCE: Calculated from Tables 5.2 and 5.10.

NOTE: Maximum = seizures as a fraction of the *minimum* official estimate of imports; minimum = seizures as a fraction of the *maximum* official estimate of imports.

percent at the beginning of the period and as high as 25 percent at the end.

It is also worth comparing the figures for replacement cost of interdiction seizures with estimates of total expenditures on the two drugs. The official figures for total consumption and retail prices suggest total cocaine expenditures in 1985 of approximately $25 billion. The replacement cost of interdiction seizures in that year was no more than $1 billion and perhaps only $500 million. Replacing seized cocaine is thus not a major share of the cost of getting cocaine to final consumers.

The marijuana figures do not permit such a definite conclusion. Total sales revenues (using official data) in 1985 were approximately $13 billion. The replacement cost for seized marijuana varies a great deal according to whether the export or import price is used. The import price would point to a replacement cost of about $1.4 billion, while the export price would lead to an estimate of only about $20 million.

With respect to the distribution of imports across modes (private plane, commercial vessel, etc.) or across routes (Colombia to southern Florida, Colombia via Mexico to the Gulf, etc.), the level of uncertainty about quantities is even greater. The existing estimates, most of them provided regularly by the Customs Service, are largely driven by seizures, i.e., they assume, as a first approximation, that the probability of interdiction is equal for all modes and routes of smuggling. For air smuggling, account is also taken of the number of plane crashes and planes stolen in a particular sector. But there are no means available for testing the formula that has been used to develop these estimates.

Other official estimates seem to be entirely driven by patterns of seizures.

Intuition suggests that interdiction rates are likely to be very different for the various modes and routes. Some modes are less susceptible to interception than are others. Land crossings of the Mexican border seem to have a low probability of interception, both because of current interdiction resource allocations and the border's inherent vulnerability. The probability of interception of marine shipments of marijuana, from Colombia at least, seems relatively high. But one cannot go beyond such broad statements without data on the smuggling experiences of those who have been caught, and such data are not currently being collected.

Any analysis of the efficacy of interdiction is sensitive to estimates of the scale of imports and their distribution across modes. To examine this sensitivity, we developed estimates of the impact of military assets under various assumptions about the scale of imports of marijuana and cocaine and their distribution among modes and routes; these estimates are given in Crawford and Reuter (1988).

Risks to Persons

To estimate the extent to which interdiction puts participants at risk of imprisonment, we must have estimates of the numbers of persons involved in smuggling. There are both conceptual and empirical problems in developing such estimates.

The conceptual problem is determining who should be included in the smuggling population. Clearly, we must include those who fly planes or crew boats. But what about those who load or unload the vessels? The Coast Guard's interdiction activities do not put them at risk, since they are not at sea, the point of Coast Guard capture. On the other hand, the Customs Air Branch attempts to put unloaders at risk by making their captures at points of landing and unloading. As the figures in Table 5.8 show, the majority of Air Branch arrests were of persons other than pilots.

The simplest base for calculation of risks to individuals is the single trip, i.e., we seek to estimate the expected prison times for an individual who agrees to serve as a crew member, pilot, etc., on a given smuggling trip. In particular, we are interested in how this number has changed over time.

In this report, we present the calculations for only one mode of smuggling, private vessel shipment of marijuana, and for one interdiction agency, the Coast Guard.

The estimation of risk for 1981 and 1985 is calculated with the following equations:

$$MI = MC - MD - MX \tag{1}$$

where MI = Total marijuana imports by sea
MC = Marijuana consumption (from the NNICC consumption estimate)
MD = Domestic production of marijuana (NNICC)
MX = Mexican production of marijuana (NNICC)

$$NT = MI / VC \tag{2}$$

where NT = Number of smuggling trips
MI = Total marijuana imports by sea, estimated by Eq. (1)
VC = Average vessel capacity (reported USCG marijuana seizures per vessel)

$$MT = AC \times NT \tag{3}$$

where MT = Number of man-trips
AC = Average crew size (reported USCG arrests per vessel)
NT = Number of trips, estimated by Eq. (2)

$$PA = AR / MT \tag{4}$$

where PA = Probability of arrest by Coast Guard
AR = Number of Coast Guard arrests for drug smuggling
MT = Number of man-trips, estimated by Eq. (3)

$$R = PA \times PC \times AS \tag{5}$$

where R = Risk, expected months of incarceration per man-trip
PA = Probability of arrest, estimated by Eq. (4)
PC = Probability of conviction (the data on convictions resulting from arrests in 1985 are limited because of the large number of cases still pending, so we have assumed the probability of conviction to be constant)
AS = Average sentence, in months (average federal sentence for marijuana)

The result of these calculations, using the lower NNICC estimates of marijuana consumption presented in Table 5.12, show a decline in a crew member's risk from 5.2 months in prison per trip to 2.9 months between 1981 and 1985. If we use the higher NNICC figures, the risk falls from 3.6 months to 2.2 months over the same period.[5] Given the relatively small change in the average DEA cannabis conviction sentence, this decrease in risk is a result of the falling probability of arrest, which in turn is driven by the reduction in the average size of shipments.

Table 5.12

CALCULATION OF RISK TO A CREW MEMBER ON A MARIJUANA SMUGGLING VESSEL, 1981 AND 1985

Item	1981	1985	% Change
Vessels	184	184	0.0
Arrests	939	724	−22.9
Marijuana seized (metric tons)	1653.4	846.1	−48.8
Vessel Average			
Crew	5.1	3.9	−22.9
Cargo (metric tons)	8.99	4.60	−48.8
Total marijuana imports (metric tons)	8,700	9,447	8.6
Total marijuana by sea	8,400	7,986	−4.9
Number of trips	935	1,737	85.8
Trips × avg. crew	4,771	6,833	43.2
Probability of arrest (arrests/man-trip)	0.20	0.11	−45.0
Probability of conviction	0.6	0.6	0.0
Avg. DEA cannabis conviction sentence	44	46	4.5
Risk (months)	5.2	2.9	−44.2

SOURCE: Calculated from U.S. Coast Guard, DEA, and NNICC data.

Prices

As already indicated in Sections I and II, we make extensive use of the difference between export and import price as a measure of inter-

[5]Using the low NNICC estimates, the risk estimates for 1982, 1983, and 1984 are, respectively, 4.4, 2.6, and 4.7. The higher NNICC values produce risk estimates of 3.7, 2.1, and 3.2 for the same years.

diction effectiveness. Here we present the available data on the behavior of this differential in recent years.

The data are, unfortunately, extremely limited. The DEA is the principal source of import price data and one of two sources of export price data; the other source being the Central Intelligence Agency. The DEA was able to provide us with only the most summary figures on export prices for marijuana and cocaine, and only for the years 1983 to 1986.

No import price data as such are available; therefore, the DEA provided its price data on large cocaine and marijuana transactions for the seven quarters from the first quarter of 1985 to the third quarter of 1986. For earlier years, we can present only summary data on large transactions. Table 5.13 gives the available figures for 1981 to 1986. In the remainder of this section, we use the term *import price* to describe the price in large transactions recorded by the DEA. This certainly overstates the absolute price but may do little to trends over time (see Appendix B).

The most striking feature of the price data is the sharp decline in the wholesale price of cocaine, despite the apparently rapid increase in total demand. The estimated price at the kilogram level was about $60,000 in 1982 and declined to about $35,000 by the third quarter of 1986. We have made some adjustments to the price data, described in Appendix B, and have reestimated the price series for the seven quar-

Table 5.13

EXPORT AND IMPORT PRICES OF COCAINE AND MARIJUANA, 1982–86

(In $ per kilogram)

Drug	1981	1982	1983	1984	1985	1986
Cocaine						
Export	NA	NA	9,100	5,150	6,250	7,000
Import	60,000	60,000	50,000	45,000	40,000	35,000
Difference	NA	NA	40,900	39,850	33,750	28,000
Marijuana[a]						
Export	NA	NA	14.5	12.5	11.5	8
Import	600	600	475	500	450	700
Difference	NA	NA	460.5	487.5	438.5	692

SOURCE: Drug Enforcement Administration, U.S. Department of Justice.

[a]Import price is at the 1-pound level for marijuana. Recent DEA figures indicate that the vast majority of wholesale marijuana purchases are in quantities of over 100 pounds.

ters. The reestimated series still makes clear that prices have declined substantially and rather steadily.

The differential between export and import prices has also fallen for cocaine, though not as sharply as the import price, because of a sharp decline in export prices. That decline itself is a phenomenon of some interest, since a number of extremely large seizures have been made in source countries, along with a relatively intense enforcement effort against cocaine exporters in Colombia.

There is no such clear trend in import prices for marijuana. A major problem of interpretation here is the apparent increase in the potency of marijuana; the higher price in 1986 compared with 1981 may represent increases in the tetrahydrocannabinol (THC) content. The DEA reports that THC content for commercial grade marijuana averaged 3.62 percent in June 1986, compared with 2.94 percent in 1983. A University of Mississippi project to monitor the amount of THC in samples of marijuana seized by law enforcement officials found that the THC level rose from less than 0.5 percent in 1973 to close to 4 percent in 1984. Thus the increased price may merely be payment for higher quality.

The DEA publishes summary figures for retail prices. However, we are not able to use these figures. The cocaine prices contain no data about purity, but anecdotal data suggest that the purity of a street gram has increased substantially since 1981. The published marijuana prices simply cover too large a range to permit analysis of year-to-year variation, even though there are now separate series available for different grades of the drug.[6]

CONCLUSIONS

The interdiction program has performed very differently for marijuana and cocaine. Although marijuana seizures have generally declined, and arrests (as measured by Coast Guard arrests, since the vast bulk of the Coast Guard effort is aimed at marijuana) have not shown any significant increase, the system may have had significant effect. The import level price of marijuana may have risen, though demand probably has fallen. The impact of interdiction on consumption has been limited by the growth of the domestic sector.

The results for cocaine are much more troubling. Very large increases in both the quantity seized and the interdiction rate have

[6]The 1987 NNICC report shows a price range of $50 to $100 in 1985 for commercial-grade marijuana; the 1986 report shows a range of $45 to $120. This does not permit a statement about the direction of change.

been accompanied by sharp declines in the import price. The cocaine smuggling system continues to grow.

We can gain some insight into this paradox by asking what determines the level of seizures. We offer a brief analysis below, specifically tailored to explain the observations regarding cocaine smuggling.

Three variables seem of first-order importance in determining the quantity of the drug seized: the quantity shipped, the quantity (and quality) of interdiction resources, and the care taken by smugglers to avoid seizure. As the quantity shipped rises, the other two variables being held constant, the quantity seized should rise; however, the interdiction rate (seizures divided by shipments) should decline.[7] The greater the care taken by smugglers, the lower the number of seizures, holding shipments and interdiction resources constant.

What determines the care taken by smugglers? Perhaps the most important factor for those modes of smuggling that impose minimal risk on agents (e.g., commercial aircraft cargo) is the replacement cost of drugs. Assume for the moment that the export price of drugs is an adequate surrogate for the replacement cost. We would expect the care taken by cocaine smugglers to have declined very substantially, since export prices have fallen sharply.

The rise in seizure quantities and rates for cocaine in the past five years may then be explained not only by the increase in resources devoted to interdiction, but also by the reduction in care by smugglers, who are willing to increase the average size of shipments (and the seizure data point to a manyfold increase in that size) because replacement costs have gone down. The preferred combination of drugs and other items in a smuggling shipment will have shifted to being more "drug intensive," so to speak.

We offer this not as the definitive explanation of the recent past, but as an indication of the need to develop more refined models of the smuggling sector and its interaction with interdiction resources if we are to understand the performance of the interdiction system. The next two sections present such models.

[7]The decline in seizure rate is a result of the use of a fixed level of interdiction resources against a larger flow of drugs.

VI. MODELING ADAPTATION BY SMUGGLERS

This section presents results from runs of our SOAR (Simulation of Adaptive Response) model, which takes account of adaptations by smugglers to the strategies of interdiction agencies. We trace how this adaptation affects the ability of increased interdiction efforts to reduce drug use in the United States. The section begins with the basic rationale of the model. We then describe the output of some early runs, using educated guesses for the critical parameters. Results are also given from a somewhat more elaborate model which introduces effects of feedbacks of smuggling cost increases on retail and export prices. Finally, we present an interpretation of the results in terms of interdiction effectiveness and the cautions that are necessary. A more complete exposition of the model, including a detailed listing of inputs, outputs, and sources, is provided in Crawford and Reuter (1988).

We reiterate here that we chose to develop a simulation model rather than estimating the parameters of a behavioral system simply because of data constraints. The simulation model permits us to incorporate data sources of varying quality and to fill in blanks with educated guesses where there simply are no data. We have attempted to compensate for this uncertainty about parametric values by using ranges of values where we are particularly uncertain.

The rationale of the model is straightforward and ignores the complexity of market strategic behavior discussed in Section VII. As the perceived risks associated with particular routes and modes of smuggling a particular drug change, so does the smuggler's preference among modes of operating. His costs also change. Increasing the risks associated with one route/mode, leaving all other risks unchanged, changes the distribution of routes/modes by which a drug enters the United States and increases the total cost of bringing in a given total quantity.

Increased smuggling costs raise the retail price by an absolute amount that is somewhat larger than the rise in the import price, since increases in the import price raise the certain costs for domestic distributors, as discussed in Section II. It is this impact of higher interdiction rates on retail price, modeled very simply in SOAR, that leads to a reduction in consumption.

THE DYNAMIC NETWORK MODEL

Several studies have developed models of drug smuggling and interdiction. Those of Boeing and the Center for Naval Analyses (Mitchell and Bell, 1980) could be considered as starting points for our analysis. These models estimate the effectiveness of additional assets in increasing the probability of interdiction in certain geographical areas. Unfortunately, these models and the others we have reviewed assume that the quantity smuggled and the means of smuggling through given areas remain constant, regardless of the level of interdiction.

In estimating the effect particular assets could have on the amounts of drugs seized, or the effect of seizures and interdiction on the cost of smuggling drugs, these models disregard the ability of the smugglers to adapt and change their mode and locale of operation. Thus they may overstate the effectiveness of a given asset. We have discarded the static approach in favor of a dynamic (not steady-state) network model.

The network model considers several routes from drug sources in Central and South America to the consumer in the United States. Routes are treated as generic, i.e., no effort is made to associate particular geographic routes with particular parameters. The model initially ignores all distribution costs within the United States; it is assumed that the smuggler's goal is merely to get the drugs into the United States. Later in this section, we add a very simple sector which infers increases in retail prices from increases in smuggler costs.

Like all models, SOAR is built around some simplifying assumptions. The amount the smuggler desires to send in any one shipment is fixed and is an input to the model; that is, we specify the amount that the smuggler wants to send each time. However, as explained below, this still allows for variation in actual shipment size for different modes of importation, since some modes do not permit the smuggler to dispatch as much in a single shipment as he would like.

The mean time between shipments is fixed and is also an input. The total quantity shipped and the quantity arriving vary from run to run. To make the results of a series of runs comparable, the initial model also linearly extrapolates the results up or down to simulate a predetermined quantity successfully imported. Later, we consider the effect of allowing feedbacks to consumption and export prices that will lead to variations across runs in the total amount imported.

The availability of drugs in the source country is assumed to be unconstrained, but the export price is an input and may vary from run to run. The first set of runs ignores such variation. The smuggler's strategy is to get the total quantity of a drug from the source to the

United States at the lowest cost. Here, cost is a comprehensive measure that includes risk compensation pay to agents, as well as the replacement costs of the drugs, property, and trained people at risk, plus operating costs. The risk compensation pay required to smuggle drugs over a given route is driven by the smugglers' perception[1] of the risk on that route.

The model not only allows a choice among different routes and different modes (air, sea, or land) at any given time, but also allows the modeling of the dynamic changes of smuggler preferences over time as perceptions of the risks associated with different routes and modes change. In addition, the model allows major, but predetermined, shifts in the deployment of DLE assets. That is, it is assumed that interdictors can move resources so that the risks associated with smuggling along a particular route (which we denote as the probability of interdiction, PI) can be raised for a period of time. Figure 6.1 presents the basic logic of the model.

Minor shifts in the allocation of DLE forces are modeled with the assumption that the cost to ship a given quantity of drug over a given route is an increasing function of the total quantity shipped over that route (see the discussion below on the choice of the parameter r). The smuggler's observations of successful interdictions and successful shipments determine his perceptions of the risk along any given route. It is assumed that he has access to the experience of all smugglers in making that estimate.

The smuggler is faced with a version of what is known as the two-armed-bandit problem, in which a gambler has the option of playing either arm of a two-armed slot machine (or either of two one-armed slot machines), each one having an unknown, and different, probability of loss. The gambler's optimal strategy, given no information about the probability of loss for either arm, is to predominantly play the machine that has given him the best ratio of winnings to attempts and occasionally play the other machine to ensure that he is not being permanently misled by the luck of past plays.[2]

Mathematically, the smuggler faces a harder problem than the gambler: Not only does the smuggler have the option of multiple routes and methods of smuggling but, as the DLE forces change the focus and deployment of their interdiction assets, the risks of interdiction change over time in ways unknown to the smuggler.

[1]We assume here that agents are as well informed about the risks associated with particular routes as are smugglers.

[2]For a full exposition of this analysis see Berry and Fristedt, 1985.

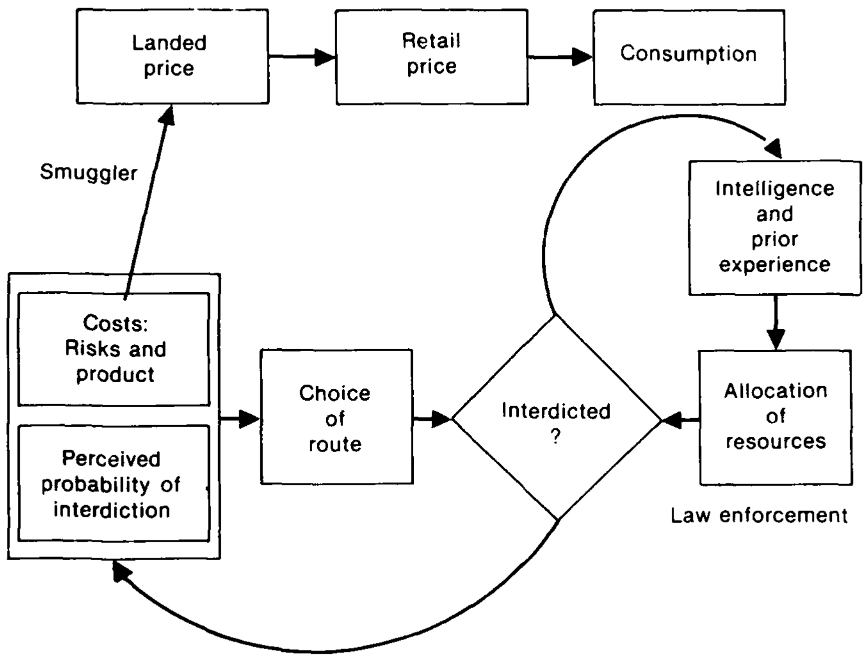

Fig. 6.1—The SOAR model

We have assumed a strategy for the smuggler that is in keeping with the spirit of the optimal solution to the two-armed-bandit problem and the dynamic nature of the problem: The smuggler computes time-weighted estimates (more recent history is weighted more heavily than older history) of the probability of interdiction along every route and then randomly chooses a route on the basis of these relative estimates of interdiction—the seemingly safe routes are chosen more often than the seemingly more dangerous ones.[3]

The model is a Monte Carlo model with a randomized choice of routes for smuggling. The smuggler's random choice of routes is tempered with observations of past successful and unsuccessful smuggling attempts along each given route. The model allows "safe" but expensive routes in an effort to model the likelihood that the DLE is unable to completely stop the flow of drugs despite any reasonable level of

[3]This simple scheme of incorporating feedback of past outcomes to alter the likelihood of the future choices of routes is often referred to as "artificial intelligence."

spending for interdiction. We would expect that these routes will become increasingly heavily used as other routes become riskier.

The inputs to the model include the PI for each route. Varying PI models the time-phased placement of DLE interdiction assets, i.e., the movement of additional resources to particular smuggling routes. It is assumed that the location of DLE assets can be made known to smugglers either immediately through direct observation of DLE assets, such as a Coast Guard or Navy blockade,[4] or implicitly with a time lag, through the observation of successful and unsuccessful shipments.

Very little of the structure of the model is rigorously defensible; too little is known about the operation of smuggling markets to permit formal estimation of the important relations. Our goal is to capture the important facets as well as is practicable. When given a choice among assumptions in the absence of data, we have generally chosen the assumption that is most likely to produce a finding of effective interdiction.

The model may be simplified when applied individually to marijuana or cocaine—some of the legs may be deemed unimportant for a particular drug. The intent is to build a general model and make it applicable to individual drugs by suitable choice of parameters.

The cost of shipping a quantity q of a drug through a given route is $aq + bq^r$, where a and b depend on the sector and the drug. We assume that r, the saturation factor, is greater than one. This implies that as a sector becomes more heavily traveled, it will become increasingly well known and understood by the DLE forces. They will react[5] by attempting to stem the flow of drugs through that sector (i.e., by moving resources so as to maintain the specified probability of interception), which is assumed to increase the cost of smuggling a given marginal quantity of drugs through the sector.

Setting $r > 1$ models the idea that increasing the quantity moved over a route increases the per-unit cost of smuggling over that route. This assumption is biased toward showing effective interdiction. The alternative is to assume "flooding," in which fixed interdiction resources become less effective as smuggling along one channel increases. We have chosen to increase the per-unit smuggling costs as traffic increases for two reasons: First, the bias is appropriate (we should assume responsive enforcement), and second, it is mathematically convenient for the network approach. In a steady-state solution

[4]Observation of a blockade, such as the Hat Trick operations off the coast of Colombia, is interpreted in the model as being equivalent to a route probability of interception of 1 and leads to the closing down of that route during the period of the blockade.

[5]Regardless of the input variables that describe the time-phased deployment of DLE assets.

(where the DLE forces do not change in time), if $r \leq 1$, this approach would result in all the drug traffic always going through one leg; clearly, this does not describe reality, since each drug actually comes through many routes.

This network model has the property that when $r > 1$, if the DLE forces do not change in time, the smuggler's strategy will converge to a minimal-cost solution, which also happens to be an equal-cost-per-leg solution. That is, the smuggler will face the same marginal cost to ship an additional small quantity of a drug through any leg. In the dynamic model, the smuggler's strategy is to move toward the perceived minimal-cost solution, bearing in mind that this solution is a moving target.

The model assumes that the smuggler's cost of using a given route[6] is driven by several factors, including the capital cost of the mode of transportation (buying a vehicle, or compensation for stealing a vehicle), the marginal cost of transportation, the time and distance involved (at least to the extent that they affect the marginal cost of transportation), and the probability of interdiction.

The interdiction rate affects smugglers' costs in a number of ways. As the rate rises, agents (pilots, crewmen, etc.) will demand higher payments for incurring greater risk of imprisonment. We have assumed that the actual risk compensation pay varies as the square of the perceived probability of interdiction (PPI). This probability is generated in the model through smugglers' weighting of past experiences. The assumption that the required payment rises with the square of the risk is consistent with risk aversion on the part of the agents. If this is incorrect, the model will tend to find more impact from increased interdiction than it would if the agents were risk-neutral.

Higher interdiction also may raise the replacement cost of seized drugs. As shown in Appendix A, higher seizure rates, under quite plausible assumptions about the elasticity of demand for drugs, will lead to an increase in total export demand. To persuade farmers to grow more and processors to refine more, smugglers may have to offer higher prices at the point of export.

The other components of cost are not affected by the probability of interdiction. The *cost to ship* includes the fixed costs other than risk compensation, i.e., costs for labor that is not at risk, fuel costs, costs associated with the use of a vessel, etc. The *cost if interdicted* represents the legal fees and other costs to replace seized assets and personnel in the event a shipment is interdicted. It does not include

[6]From this point, we shall use the term *route* to describe a particular choice of mode of transportation and geographic path from the source country to the United States.

the cost of the drugs seized; that is computed from the shipment size and the export cost of the drug.

To implement the model, we have sought estimates of:

- Quantities shipped, by route, in a given year.
- The number of shipments, by route, in a given year.
- The number of vessels identified as suspicious, by route, in a given year.
- The number of suspicious vessels pursued, by route, in a given year.
- The number of pursuits that result in seizures, by route, in a given year.
- The compensation resulting from the likelihood of prison.
- Smugglers' non-risk compensation costs and profits.

We have been able to obtain data on only a few of these parameters. The simulation results reported below use informed guesses for many of them.

Existing estimates of the overall interdiction rate in a particular sector, regardless of the mode of smuggling, are of questionable accuracy. A good estimate of the interdiction rate along a route can be made only if there is good information about the amount of a drug being smuggled over the route. When intelligence about the total flow through a sector is available—a rare occurrence—it is apt to be used to disrupt the smuggling along that route and hence ceases to be descriptive of activity there. For these reasons, we have been forced to rely on global estimates of the overall interdiction rate based on seizures and estimated consumption. We have assumed in our base case (which provides the benchmark for evaluating the impact of additional interdiction resources) that the probability of interdiction is equal on all routes/modes, except the relatively expensive and safe land route.

For our needs, estimates of the increases to interdiction rates that can be realized by using DoD assets are more important than precise estimates of current rates of interdiction. We intended to base our estimates of these changes on data from the Customs Service and the Coast Guard. We planned to make estimates of the last two conditional probabilities in the chain of conditional probabilities that describe the interdiction process (i.e., the conditional probability of pursuit, given that the vessel is suspicious, and the conditional probability of seizure, given that the vessel was pursued) from these data. These estimates would then be used to judge the potential increase in PI that [illegible] be effected on each route.

We have received a certain amount of data from both the Coast Guard and Customs. The Coast Guard data (SEER), described in Section III, have proven very helpful. Unfortunately, it was not possible to extract from these data estimates of the number of vessels pursued, since the dataset moved directly from identification (which might be made by an aircraft) to boarding. Data were also provided by the Customs Air Branch, also described in Section III. Our analysis of those data indicates that they must be interpreted with considerable care. For example, the San Diego Customs Air Branch data show that requests for launches by pursuit aircraft frequently cannot be satisfied because there are no ready aircraft. In contrast, the same dataset for the Miami Air Branch shows that this never occurs there. We have been led to believe that the difference may be in reporting habits, not in the actual readiness and size of the two air fleets.

There are other areas as well where the data must be interpreted with the help of expert judgment and observation of personnel in the field. Unfortunately, we have not been able to obtain enough data to make such detailed investigations. We have instead evaluated the effectiveness of a range of potential increases in PI. We have generally chosen increases to establish an upper bound for the potential impact of military resources.

DESCRIPTION OF SOAR RUNS

The model assumes that the smuggler's objective is to get the desired amount of a drug into the United States at a minimum cost. In the initial runs, the prime criterion for judging the effectiveness of DoD assets in the interdiction process is the total increased costs to the smuggler resulting from the use of these assets. Other measures of effectiveness generated by the model are quantities seized, the seizure rate, and the number of successful interdictions.

These initial runs ignore interactions between smugglers' costs and drug consumption and production decisions. They can be interpreted as assuming either that consumption is unaffected by retail price or that retail price is unaffected by smugglers' costs; on the export side, they amount to the assumption that either exports to the United States are a very small share of total production or that there is a flat supply curve for the drug.

We include these runs because they focus attention on the factor that is most directly affected by interdiction, i.e., the costs that will be incurred by smugglers. However, the ultimate goal of interdiction is to reduce drug consumption. Hence the later runs permit feedbacks from

increased smuggler costs to total consumption and from increased seizures to the replacement cost of the drugs to smugglers. These later runs are referred to as the *full model runs.*

We made three types of runs with SOAR. The first were simply intended to verify that the model functioned and that it did not produce obviously perverse results. The process uncovered a few errors, but, with minor exceptions, the model logic seems to have been implemented as designed and the design seems complete. It has not yielded counterintuitive answers in the contingencies and scenarios that have been modeled.

For example, a series of SOAR runs were made for scenarios in which all routes have identical interdiction probabilities and infrequent shipments do not saturate routes (in the sense that the saturation factor r does not drive up the cost of using the route). The proportion of shipments interdicted in the model should be close to the probability of interdiction, which is an input. These scenarios can be analyzed with back-of-the-envelope calculations—upper bounds on the experimental error are easy to compute. The differences between the proportions computed in the model and the input probabilities have been small and well within the range of expected experimental error.

Another of the exploratory run series held all parameters constant, except the mean time between shipments and the shipment size, i.e., a smaller number of larger shipments were dispatched within the model. Both of these parameters were increased by the same multiplicative factor. The results were as expected: Most output statistics remained relatively constant, but as shipment size increases, the amount shipped over a route per unit time becomes more random. As this occurs, routes occasionally become randomly saturated, and the proportion interdicted rises. This reflects our assumption that interdiction agencies react positively to increased flow rather than becoming flooded.

In another series of runs, the parameters describing different routes were varied to make individual routes relatively advantageous or relatively expensive. The resulting proportions of drugs shipped along each route were compared with proportions prior to adjusting the parameters. The long-term averages of the amount of drugs shipped, by route, were as expected—the more expensive routes were rarely used, and the less expensive ones dominated.

These runs have provided confidence that the results of the model are, within experimental error, equal to the expected results from a detailed analysis of these simplistic scenarios.

The second set of runs represents our first explorations of the policy-relevant question, What is the effect of smuggler adaptation?

Adaptation can be modeled in two dimensions, geography and time; we can also model adaptation of both the smugglers and the DLE. The SOAR model allows all of these adaptive strategies.

These SOAR runs incorporate eleven "routes," representing different possible combinations of geographic routes and modes of transportation for smugglers. The first ten routes are equally divided between air and sea routes for the cocaine runs. The preference of marijuana smugglers for sea and land routes is reflected in the choice of four air routes, five sea routes, and two land routes in the marijuana runs. In both sets of runs, route 11 is an expensive land route with a PI of 0.10. The PI on route 11 is not increased in any of the following runs. Route 11 is intended to model methods of smuggling whose risk is difficult to raise regardless of the level of DoD participation in interdiction, such as smuggling through ports of entry or across remote areas of the Mexican border.

The third series of runs (the full model runs) incorporates the feedbacks to consumption and production described above. These runs differ from the second series in that the quantity landed varies from run to run, and this quantity is the prime criterion for judging the effectiveness of additional interdiction resources.

THE COCAINE RUNS

The Input Data

The inputs for the base-case cocaine run are summarized in Table 6.1. (In this table and others in this chapter, all costs and weights are given in dollars and kilograms, except where noted.) The average shipment was sized at 250 kilograms to approximate the average seizure reported in the available data (see Section V), excluding small seizures. Small seizures were excluded in an attempt to more accurately model the serious professional smugglers who bring in the bulk of imported drugs.

The mean time between shipments was set at 0.71 days, resulting in approximately 1.4 shipments per day, or 500 shipments per year. Since the model uses a Monte Carlo procedure, these inputs determine the average number of attempts, but the amount delivered is random. To make the different runs in the initial set comparable, the model also scales the results. For the cocaine runs, the results are scaled to give an average of 350 kilograms successfully delivered per day, or 127.75 metric tons of cocaine per year. This figure is in agreement with the data of Section V, linearly extrapolated to 1986.

Table 6.1

SUMMARY OF INPUTS FOR COCAINE RUN 1: BASE CASE

(120 days of run to initialize perceived probabilities of interdiction; 365 days to be analyzed; 127.75 metric tons of cocaine to be successfully imported)

Item	Value
Cocaine	
Export cost per kg ($)	7,500.00
Expected time between shipments (days)	0.71
Shipment size (kg)	250.00
Avg. amount to be delivered per day (kg)	350.00
Routes 1–5, by air	
Cost to ship ($)	20,000.00
Initial interdiction probability	0.20
Risk compensation ($)	1,200,000.00
Cost if interdicted ($)	200,000.00
Maximum shipment size (kg)	2,000.00
Routes 6–10, by sea	
Cost to ship ($)	16,000.00
Initial interdiction probability	0.23
Risk compensation ($)	1,600,000.00
Cost if interdicted ($)	40,000.00
Maximum shipment size (kg)	16,000.00
Route 11, by land	
Cost to ship ($)	120,000.00
Initial interdiction probability	0.10
Risk compensation ($)	10,000.00
Cost if interdicted ($)	5,000.00
Maximum shipment size (kg)	50.00
Summary of inputs, runs 2–8	
Run 2, as in run 1, except PI = 0.5 on one fixed air route	
Run 3, as above, except PI = 0.5 on two fixed air routes	
Run 4, as in run 2, except PI = 0.5 on one random air or sea route	
Run 5, as above, except PI = 0.5 on two random air or sea routes	
Run 6, as above, except PI = 0.5 on three random routes	
Run 7, as above, except PI = 0.5 on five random routes	
Run 8, as above, except that PI = 0.5 on ten routes	

Assuming an aircrew size of one or occasionally two people with reasonably high legitimate earning potential, the risk compensation (defined below) was set at $1,200,000 for air shipments. Ship crews are much larger—four or five is common. On the other hand, the potential earnings of most of the crew are much smaller, so the risk compensation for the entire crew was set at $400,000 for sea shipments. To reflect the lack of earning potential of the single smuggler who carries cocaine over the border, $10,000 was set as the risk compensation for land shipments. These figures are the totals that must be paid by smugglers to their agents if the PPI is 0.5, the norming factor for risk compensation throughout the analysis.

As already mentioned, the model assumes that risk compensation pay varies as the square of the PI. Thus, if the PI is 0.25 for an air shipment, the risk compensation pay is $\$1,200,000 \times (0.25/0.5)^2$, or $300,000. If the PI is 0.10, the risk compensation for air shipments is $\$48,000$, $\$1,200,000 \times (0.1/0.5)^2$. The assumption of such a relationship ensures that large increases in the risk of capture will have very large impacts on smuggler labor costs. We believe that this is a reasonable assumption, particularly for pilots.

Inputs to the model include maximum shipment size, by method of smuggling. If the maximum shipment size for a method is less than the shipment size specified for the drug, multiple shipments are made when that method is chosen. We have chosen a maximum shipment size of 700 kilograms for air shipments as a reasonable approximation of the carrying capacity of the medium-weight twin-engine aircraft that seem to be preferred for air smuggling. For sea shipments, the maximum shipment size is set at 16 metric tons. Both of these limits exceed the shipment size for cocaine and hence do not affect the cocaine runs. On the other hand, the shipment size for smuggling across the U.S.-Mexico land border may be approximated by a man's carrying capacity, over rough terrain and in a hostile environment. We estimated this capacity to be 50 kilograms. For land shipments, the model calculated five individual shipments to achieve the desired shipment size.

The Base Case

There are actually two "probabilities of interdiction" that could be of interest here. One is the probability that a randomly chosen *kilogram* of a drug is seized in the interdiction process; the other is the probability that a randomly chosen *shipment* gets seized.

In this model, the second of these is the PI. To obtain an estimate of PI, we divide the interdiction rate, as measured by the number of

shipments interdicted, by the number of shipments attempted. This is the appropriate PI for measuring the risk to which smugglers' agents are exposed, since the number of individuals associated with a shipment is very insensitive to shipment size.

The probability of a random kilogram being seized is estimated by dividing the quantity seized by the quantity attempted. This is called the seizure rate. If all shipments are of the same size, or all routes have the same PI, these probabilities will be equal. Neither happens in the SOAR runs, and a disparity between the interdiction rates (as defined above) and the ratio of seized tonnage to attempted tonnage is to be expected.

The interdiction rate is likely to be lower than the seizure rate because larger shipments are more vulnerable than smaller shipments. Larger shipments tend both to be carried in more conspicuous vessels and to be more readily found if a carrying vessel is searched. The smuggler may choose to use large shipments, even though they are more vulnerable, because their per-unit risk and transportation costs can be lower.

The PIs for the routes of the base-case run (run 1) are shown in Table 6.1: 0.20 on the air routes, 0.23 on the sea routes, and 0.10 on the expensive land route. In the output of run 1, the overall interdiction rate was 0.18, in reasonable agreement with current estimates of interdiction effectiveness. Also in agreement with extrapolations of the seizure data reported in the 1984 NNICC report, 31.4 metric tons were interdicted. Only 8 percent of the cocaine was shipped over the expensive land route; most of it was shipped by air.

The value of these runs lies not in their ability to play back reasonable numbers, but in the capacity they provide to investigate the effects of reasonable changes in PI.

Increasing the Probability of Interdiction

A brief summary of the scenarios investigated in runs 2 through 8 is given at the bottom of Table 6.1. In run 2, the PI was increased to 0.5 on one fixed route. In run 3, the PI was increased to 0.5 on two fixed routes. To investigate the effectiveness of flexibly deploying interdiction assets and moving them from route to route, the PI was increased to 0.5 on one random air or sea route in run 4, and to 0.5 on two randomly selected routes in run 5. In this context, "randomly selected" means the smuggler has no way of knowing when and where PI is going to be increased. Past experience about the interdiction rate on a particular route is not a good guide to the future rate.

We chose 0.5 as the ceiling rate, since it seems unlikely that much higher interdiction rates can be achieved along individual routes. Certainly this seems to be a significantly higher rate than is being currently attained.

The results of these variations are given in Table 6.2. The increase in PI on one fixed route resulted in a small increase in smugglers' costs (1.3 percent) and a 3.1 percent increase in the amount of cocaine interdicted. There was a small shift to increased utilization of route 11. Comparison of run 2 with run 4, where PI was also increased to 0.5 on one route but that route was varied over time, reveals a slight increase in the effectiveness of the interdiction assets when the randomization is allowed.

In run 3, PI was increased to 0.5 on two routes, and in run 5 it was increased to 0.5 on two randomly selected routes. Although 11 routes are available to smugglers, increasing PI on two routes begins to have a noticeable effect, especially if the routes are, from the smugglers' perspective, randomly selected. The increases are four times as great when the two routes are randomly selected as when they are fixed. The increase in cost jumps to 2.3 and 12.0 percent in these two runs, and the amount interdicted increases by 6.8 and 27.7 percent. In these runs, there is a continued increase in the utilization of route 11.

Runs 6 and 7 show the effect of further increases in the number of routes with enhanced PI. In run 6, PI was increased to 0.5 on three random routes, while in run 7 it was increased to that level on five (out of ten) randomly chosen air and sea routes. These runs show substantially increased costs to the smuggler—increases of 38.0 percent and

Table 6.2

SUMMARY OF SOAR OUTPUT, COCAINE RUNS 1–8

Run	Total Drug Cost ($ millions)	Replacement Cost (% of total outlay)	Increase in Smugglers' Cost (%)	Interdiction Rate	Metric Tons Int'd.	Route 11 Tons Landed	Route 11 % of Total
1	1,408	0.85	0	0.18	32.5	10.2	8
2	1,427	0.85	1.3	0.18	33.5	10.6	8
3	1,440	0.85	2.3	0.19	34.7	11.5	9
4	1,459	0.84	3.6	0.19	35.1	10.7	8
5	1,572	0.81	12.0	0.21	41.5	14.8	12
6	1,690	0.78	20.0	0.22	47.8	17.0	13
7	1,938	0.72	38.0	0.24	58.3	24.3	19
8	2,387	0.65	70.0	0.26	78.2	35.2	28

70.0 percent. As the number of routes with enhanced PI increases in run 7, the utilization of route 11 doubles and is used for 19 percent of the delivered cocaine.

Finally, in run 8 we allow for high interdiction rates on all the routes except route 11. The share of imports going through this route increases dramatically—from 19 percent to 29 percent—as one might expect when the risk is so much lower than on all the other routes. Total importing costs also increase substantially, by about $450 million.

In these runs, it is interesting to note that the obvious and tangible measure of success, the amount interdicted, increases at a much faster rate than does the measure that is more relevant to the overall effects of interdiction—the cost to the smuggler. Throughout the runs, increases in amount seized were about twice as large as the increases in cost to the smuggler. In run 7, the cost to the smuggler increased by 38 percent, but the amount interdicted increased by almost 80 percent. There are also changes in the discrepancies between the seizure and interdiction rates; the latter rises much more slowly than the former. This reflects the fact that more of the drug is crossing the land border, route 11, in smaller bundles. The effectiveness of increased interdiction clearly depends on the choice of measure. Figure 6.2 shows increases in seizure quantities and total costs, relative to the base case, as the number of high interdiction routes varies.

Increasing the interdiction rate changes the structure of smugglers' costs. Whereas the replacement cost of cocaine accounts for 85 percent of total outlays for smugglers in the base case, it accounts for only about 65 percent of the total in run 8. This reflects the impact of higher interdiction on cost items such as risk compensation for pilots. On the air routes, with a PI of 0.5, the cost is $1,200,000; for the base case, when the air interdiction rate is 0.2, the cost is $192,000.

The increases in smuggler costs, when translated to a per-kilogram basis, look quite modest compared with the final price of the drug, or even with the wholesale price. The total smugglers' cost in run 8 is only about $8,000 per kilogram higher than in the initial case; this compares with a wholesale (kilogram-level price) of about $40,000 and a retail price of about $250,000.

Increased Interdiction: Feedbacks to Consumption and Production

The third set of runs allows for increased interdiction to impact on the consumption level (as measured by the total deliveries) and the

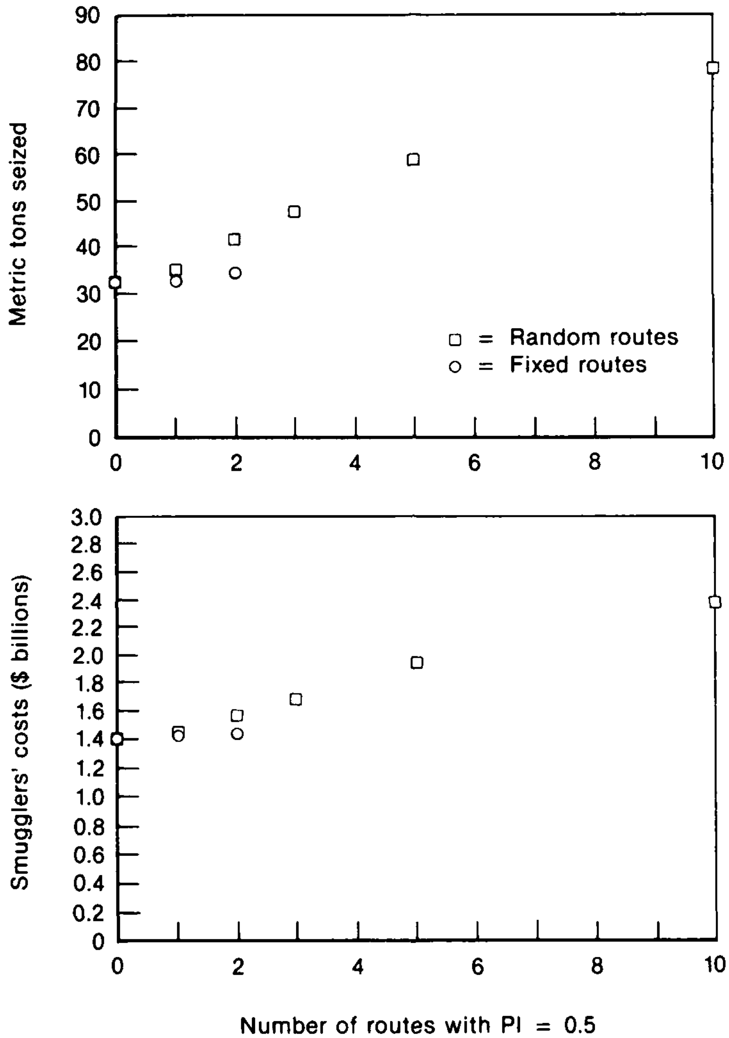

Fig. 6.2—Effects of varying the number of high interdiction routes on quantities of cocaine seized and smugglers' costs

export price of the drug. The feedbacks are modeled very simply in the following equations:

1. ed = elasticity of demand with respect to retail price = −2.0
2. ep = elasticity of retail price with respect to the import price = 0.2
3. ex = elasticity of supply with respect to total shipments to the United States = 0.5

The first equation says that a 1 percent increase in the retail price of cocaine will result in a 2 percent decrease in cocaine consumption. As argued in Section II, this certainly overstates the elasticity of demand for cocaine in the short run, given the large share of the market that is addicted. It may be more reasonable in the long run.[7]

We have deliberately chosen an assumption that increases the likelihood that interdiction will have an impact on consumption, since the preliminary analysis suggested a relatively slight effect. If consumption is very insensitive to price, then even very large increases in costs and prices resulting from interdiction will have little impact on consumption.

The same principle has guided our choice of the value in the second equation. Retail prices are currently approximately 10 times imported prices. This would suggest that, with competitive markets in the post-import distribution sectors, a $1 increase in the import price will raise the retail price by only about $1.25 (see Section II), allowing generously for the additional domestic inventory costs. That would suggest an elasticity of retail to import price of only 0.125. We have increased that to 0.2 to account for nonenforcement risks that might be heightened by the raised value of the drugs when held in domestic transactions. This will raise the likelihood that higher interdiction rates will have a large effect on domestic consumption. We have also assumed that increases in smuggler costs are fully passed on in import prices.

The third equation captures the impact of seizures on the replacement cost of drugs for smugglers. If the higher seizures do not reduce consumption (demand) by as much or more, then total shipments from the source countries to the United States will rise. To obtain that larger quantity of drugs, smugglers will have to offer higher prices.

There is no basis for systematic estimation of this price elasticity. Discussions with officials suggest that they beli ve it to be very low. In

[7]This ignores shifts in tastes that might occur in the long run, for example, if the drug acquires a reputation for dangerousness. The elasticity constitutes a statement about what would occur if the price increased and nothing else changed.

the short run, this perception is influenced by the apparent availability of very large inventories which would dampen the price impact of increased U.S. demand. In the long run, the fact that U.S. cocaine consumption is less than half of total source country production and the resources required for production (low productivity land and rural labor) are in ready supply makes it unlikely that prices would have to increase much to induce a higher supply of cocaine.

Our assumption about ex in the third equation above amounts to the assumption that a 1 percent increase in shipments to the United States requires a 2 percent increase in the export price. This is a much larger effect than we actually expect, but again, it is intended to allow for the possibility that interdiction can have a large effect on domestic consumption, since the role of ex is to allow for increase in another component of smugglers' costs as the result of interdiction.

These "full model runs" are created by a two-step procedure. We start with the output created for each run in the previous set of SOAR runs, where there are no feedbacks. A second set of equations then incorporates the feedbacks, using the same percentage seizure rate for that run in the simpler model. This latter is an assumption imposed to simplify the computation for each run; it will provide trivial, if any, distortion when the initial SOAR runs show little increase in total smuggler costs. When, as in runs 7 and 8, the smugglers' costs go up substantially, the assumption will induce some bias toward finding larger effects from increased interdiction.

With these additional feedbacks, we have a different result from the model. Instead of focusing on smugglers' total cost to ship, we now give primary attention to the impact on total consumption. The impact of allowing for these feedbacks is shown in Table 6.3, which reports outputs from the same set of runs that were shown in Table 6.2. Thus, for example, the eighth and final run is one in which all routes except the cheap land route (11) have a probability of interdiction of 0.5. The second column, metric tons landed, now shows total consumption (shipments less seizures).

The results are again somewhat disheartening. On the eighth run, when air and sea interdiction are very stringent, the net result is a reduction in total cocaine consumption of about 25 percent. That is indeed substantial, but when only some routes are subject to the higher interdiction rates, there is very little impact on total consumption. For example, when three randomly chosen routes are subject to interdiction probabilities of 0.5, total consumption is reduced by less than 9 percent. Only when as many as five routes have the higher probability, in run 7, does total consumption decrease by more than 10 percent.

Table 6.3

SUMMARY OF OUTPUT WITH ELASTICITY FEEDBACK, COCAINE RUNS 1–8

Run	Metric Tons Landed	Total Cost ($ millions)	Inter-diction Rate	Metric Tons Int'd.	Route 11 Metric Tons Landed	Export Price ($/kg)
1	127.75	1,408	0.18	32.5	10.2	7,500
2	127.02	1,427	0.18	33.3	10.5	7,508
3	126.39	1,440	0.19	34.3	11.4	7,544
4	125.83	1,459	0.19	34.6	10.5	7,515
5	121.49	1,572	0.21	39.4	14.1	7,566
6	117.18	1,690	0.22	43.8	15.6	7,573
7	109.10	1,938	0.24	49.8	20.8	7,373
8	95.18	2,387	0.26	58.3	26.2	6,862

It is also of some interest to consider export prices and quantities. Seizures, though a positive measure for interdiction forces in the United States, do create a problem for the drug control forces in source countries, since they can increase the demand for shipments and the income received by source country producers. Total export earnings can be calculated from Table 6.3 by multiplying total shipments (tons landed plus tons interdicted) by the export price. In the base case, export earnings are $1,202 million, and they rise to $1,249 million by run 6. In the final run, however, export earnings fall from the base case to $1,190 million. This occurs because other cost factors have been driven up so much that they, rather than drug replacement costs, lead to an increase in landed price and hence reduced consumption. Though the total quantity seized increases, the sum of seizures and deliveries is now less than in the base case.

THE MARIJUANA RUNS

The Input Data

The inputs for the base-case marijuana run are summarized in Table 6.4. At an export price for marijuana of $10 per kilogram, as compared with $7,500 per kilogram for cocaine, the marijuana runs would be expected to show different trends as we increase the PI. The replacement cost of drugs is likely to be a much lower share of total smuggling costs. Indeed, this is consistent with the observation that for mari-

Table 6.4

SUMMARY OF INPUTS FOR MARIJUANA RUN 1: BASE CASE

(120 days of run to initialize perceived probabilities of interdiction; 365 days to be analyzed; 6,500 metric tons of marijuana to be successfully imported)

Item	Value
Marijuana	
Export cost per kg ($)	10.00
Expected time between shipments (days)	0.28
Shipment size (kg)	5,000.00
Avg. amount to be delivered per day (kg)	17,808.00
Routes 1–4, by air	
Cost to ship ($)	10,000.00
Initial interdiction probability	0.25
Risk compensation ($)	235,000.00
Cost if interdicted ($)	100,000.00
Maximum shipment size (kg)	700.00
Routes 5–9, by sea	
Cost to ship ($)	10,000.00
Initial interdiction probability	0.25
Risk compensation ($)	300,000.00
Cost if interdicted ($)	20,000.00
Maximum shipment size (kg)	50,000.00
Route 10, by land	
Cost to ship ($)	8,000.00
Initial interdiction probability	0.30
Risk compensation ($)	7,000.00
Cost if interdicted ($)	5,000.00
Maximum shipment size (kg)	500.00
Summary of inputs, runs 2–8	
Run 2, as in run 1, except PI = 0.5 on one fixed air route	
Run 3, as above, except PI = 0.5 on two fixed air routes	
Run 4, as in run 2, except PI = 0.5 on one random air or sea route	
Run 5, as in run 3, except PI = 0.5 on two random routes	
Run 6, as above, except PI = 0.5 on three random routes	
Run 7, as above, except PI = 0.5 on five random routes	
Run 8, as above, except that PI = 0.5 on ten routes	

juana the ratio of import prices to export prices is vastly higher than for cocaine—approximately 20, as compared with 3.

Shipment sizes and mean time between shipments were chosen to be in agreement with an extrapolation of the low estimates for imports given in the 1985 NNICC report. The average amount delivered per day results in 6,500 metric tons of marijuana delivered per year. Risk compensation pay has been scaled down for marijuana, reflecting lower sentences for marijuana offenders.

The maximum shipment size for land shipments has been increased to reflect a shipment that may cross a port of entry in a vehicle or be carried across the border by ten people.

The Base Case

The amounts of marijuana delivered and seized agree with extrapolations of the NNICC data. In comparison with the cocaine runs, route 11 sees more traffic, even in the base case: 17 percent, as compared with 9 percent in the cocaine base-case run. This accords with the observation that a significant share of marijuana imports come across the Mexican land border. Since route 11 has a PI of 0.10, the overall seizure rate was reduced to 0.15.

The Results of Increasing the Probability of Interdiction

The SOAR output for the marijuana runs is shown in Table 6.5. With the higher volume of traffic over route 11, increasing PI on one fixed route in run 2 had very little effect. Traffickers were able to adapt very easily. Run 4, with PI increased on one random route, showed substantially more effect, increasing costs by 11 percent and increasing the amount interdicted by 12.1 percent.

Increasing PI on two routes again showed the great advantages of enhancing interdiction capability on random routes as opposed to fixed routes: Increasing PI on two fixed routes increased both costs and amount interdicted by less than 4 percent, while increasing PI on two random routes increased these measures of effectiveness by 24 to 29 percent.

Runs 6 and 7, where PI was increased to 0.5 on three and five random routes, show substantial increases in costs and amount interdicted. Finally, run 8 shows truly large effects on smugglers' costs. The total cost is now 165 percent higher than the baseline cost; over half of the imports are forced over the land border. The marijuana runs, even more than the cocaine runs, demonstrate the importance of flexibly deployed interdiction assets.

Table 6.5

SUMMARY OF SOAR OUTPUT, MARIJUANA RUNS 1–8

Run	Total Drug Cost ($ millions)	Replacement Cost (% of total outlay)	Increase in Smugglers' Cost (%)	Interdiction Rate	Metric Tons Int'd.	Route 11 Tons Landed	Route 11 % of Total
1	229	0.35	0.0	0.15	1,485	1,085	17
2	236	0.34	3.1	0.15	1,528	1,124	17
3	237	0.32	3.5	0.16	1,538	1,150	18
4	254	0.32	11.0	0.16	1,665	1,202	18
5	285	0.30	24.0	0.16	1,909	1,398	22
6	329	0.26	44.0	0.17	2,085	1,658	26
7	418	0.21	83.0	0.17	2,469	2,316	36
8	608	0.16	166.0	0.17	2,928	3,462	53

In the marijuana base case, the smuggler delivered 6,500 metric tons and had 1,848 metric tons interdicted, for a total of 8,348 metric tons. At an export price of $10,000 per metric ton, drug purchases comprised only 35 percent of the smugglers' cost. As a result, the marijuana smugglers' costs are heavily driven by personnel costs which increase faster as a function of interdictions than does the cumulative cost of the drug lost. In fact, the marijuana smugglers' costs actually increase faster than did the amount interdicted—83 percent in run 7 versus 66.3 percent. Initially, in runs 2 through 5, costs increase more slowly than amount interdicted, but as interdiction rates begin to rise, costs begin to increase faster. In run 8, with 10 routes subject to a high probability of interdiction, costs are driven up very substantially; they are now more than 1.5 times the baseline figure. The quantity interdicted is more than doubled. Figure 6.3 shows increases in seizure quantities and total costs, relative to the base case, as the number of high interdiction routes varies.

Increased Interdiction: Feedbacks to Consumption and Production

We now add to the SOAR model the same structure of feedbacks to consumption and production of marijuana that we used for the cocaine model. Higher smuggling costs raise the landed price and then the retail price; that induces lower consumption. The replacement cost of marijuana for smugglers (the export price) rises if total shipments (quantity landed plus quantity seized) increase. We assume the same values for the elasticities given in the first two equations above.

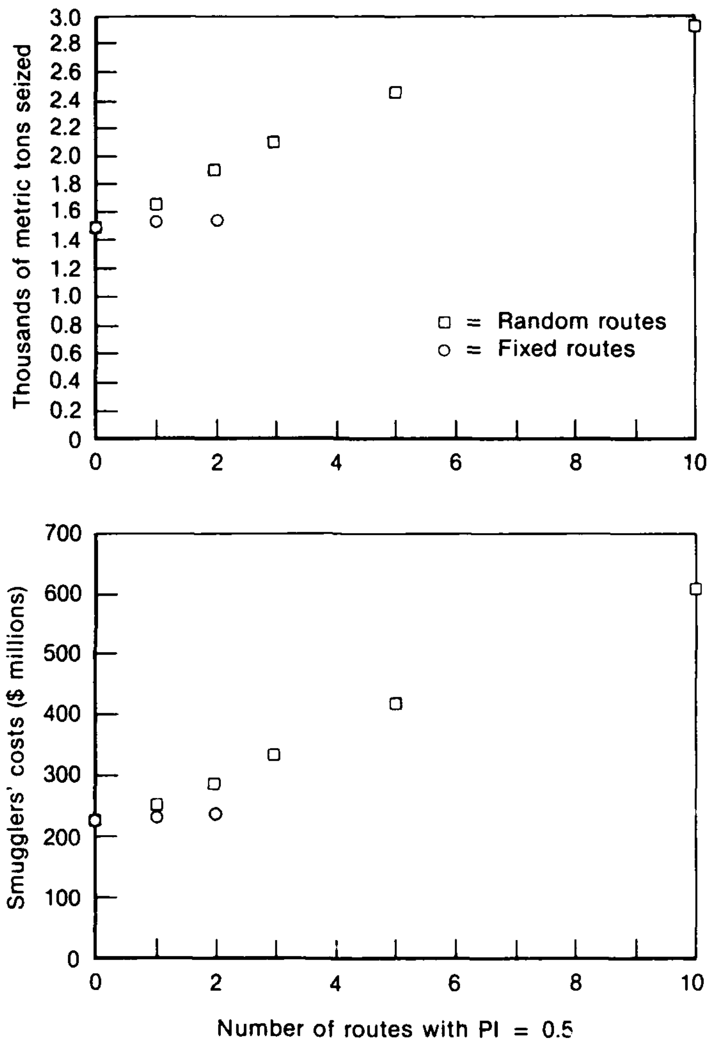

Fig. 6.3—Effects of varying the number of high interdiction routes on quantities of marijuana seized and smugglers' costs

Demand is quite elastic with respect to the retail price (a 2 percent decline for each 1 percent increase in retail price). The elasticity of the retail with respect to the import price is 0.2; a 1 percent increase in the landed price leads to a 0.2 percent increase in the retail price. We change the value of ex from 0.5 to 1.0 so that a 1 percent increase in shipments can be obtained only at a 1 percent higher price. This is less favorable to the interdictors than ex = 0.5, but with the latter value the model generated implausibly low prices (50 cents per kilo) for the later SOAR runs, as total shipments declined. It still remains a more favorable assumption for interdiction effectiveness than is likely to be the case in reality.

The assumptions about supply and demand elasticity need no further explanation beyond that given in the discussion of cocaine. However, the assumption about the elasticity of retail price with respect to the import price (ep) requires some discussion. For marijuana, the landed price is a much higher percentage of the final price than is the case for cocaine—it is about 25 percent, as compared with 10 percent. But the existence of an increasing domestic sector suggests that the increase in smuggling costs cannot be fully passed on. Some of the market will be lost to domestic producers. Thus the model allows for only partial markup of the retail price.

These are fairly arbitrary assumptions. But if they differ from the true values, they are likely to lead to a finding of a higher effect from increased interdiction than is actually the case.

The results with feedback are reported in Table 6.6. They differ in some respects from those for cocaine. Raising the interdiction rate on

Table 6.6

SUMMARY OF OUTPUT WITH ELASTICITY FEEDBACK, MARIJUANA RUNS 1–8

Run	Metric Tons Landed	Total Cost ($ millions)	Inter-diction Rate	Metric Tons Int'd.	Route 11 Metric Tons Landed	Export Price ($/kg)
1	6,500	229	0 15	1,485	1,085	10.0
2	6,425	236	0.15	1,510	1,111	9.94
3	6,414	237	0.16	1,518	1,135	9.93
4	6,231	254	0.16	1,596	1,152	9.80
5	5,897	285	0.16	1,732	1,268	9.55
6	5,439	329	0.17	1,745	1,387	9.00
7	4,516	418	0.17	1,715	1,610	7.80
8	2,588	608	0.17	1,166	1,378	4.70

a few routes has only modest effects, as reflected in runs 2 through 4. Runs 5 and 6, with two and three routes randomly subjected to the higher rates, show more substantial effects, but they still lower imports by less than 15 percent. The last two runs show very substantial effects indeed: With five random routes, imports are reduced by one third. When all but one route are subject to an interdiction rate of 0.5, imports fall by fully two-thirds.

It is also interesting to note differences in the behavior of marijuana export prices as compared with cocaine. Marijuana export prices always fall when interdiction stringency increases, reflecting the fact that the risk compensation costs are a much higher share of smuggler costs for marijuana.

CONCLUSIONS

The results of our simulation runs provide a very mixed view of the impact of increased interdiction stringency.[8] For cocaine, the results are generally quite unpromising. They suggest that unless interdiction severity can be raised on almost all the routes available to smugglers, only modest reductions in total consumption can be achieved.

For marijuana, however, it is possible to drive down total imports substantially with sufficiently stringent interdiction. The question, which could not be explored with our models, is whether this is mostly compensated for by increases in domestic production.

Two additional points must be noted. First, raising interdiction rates on a few routes seems to have little impact. In particular, raising the interdiction rate on a single route has almost no impact, particularly if it is a fixed route. Once smugglers identify a particular route as having high interdiction rate, they will simply shift to other routes, producing a slight aggregate effect. A very large share of all routes have to be subject to elevated interdiction rates before there is significant impact.

Second, random allocation can greatly increase the impact of additional interdiction resources. Smugglers can adapt efficiently only when they can form good estimates of the interdiction rates associated with particular routes. If they know that three routes will have higher interdiction rates, but they do not know which three they are, then adaptation will be relatively ineffective.

This second conclusion is not necessarily a strong recommendation that DLE resources be frequently shifted across routes. There are

[8]Additional runs with different baseline values are reported in Crawford and Reuter (1988). They provide essentially similar results.

costs to such shifts, which could not be incorporated into this analysis. Moreover, it is important not only to shift resources but to conceal the shift, and this may be difficult to do.

We conclude by reiterating certain methodological limitations of the model. We have not been able to directly incorporate a domestic production sector in the marijuana model. To prevent systematic underestimation of the impact of interdiction on import prices, we have used an elasticity of demand for imports that is greater than the elasticity of demand for marijuana.

This does not mean that the current runs underestimate the impact of interdiction on marijuana *consumption*; indeed, quite the opposite. By assuming that smugglers can pass on most of the import cost increases, except as affected by the decline in aggregate demand for marijuana, the model will lead to overestimates of the impact of interdiction on marijuana consumption.

Perhaps more troubling is the assumed efficiency of smuggler adaptation. Our model assumes that all smugglers share the same information and incorporate it relatively rapidly into their estimates of the costs of smuggling by different means. Though we have presented some evidence that adaptation occurs, the model may overstate how quickly smugglers make adjustments.

SOAR and its variants constitute an early effort to systematically analyze how interdiction can raise smugglers' costs and lower consumption. More refined, data based (if possible) versions of these models should be developed. The precise quantitative results presented here will certainly not be replicated. We believe, though, that they will replicate the finding that interdiction must be very stringent indeed to greatly affect U.S. drug consumption.

VII. THE CONSEQUENCES OF SMUGGLERS "LEARNING BY DOING"

The simulation model in Section VI assumed that smugglers adapted to changes by interdiction agencies, but that otherwise the smuggling system was static, i.e., that smugglers' costs did not change over time except in response to changes in interdiction strategies and severity. Even with adaptation, however, increased interdiction will raise smuggler costs and reduce total consumption at least somewhat, as the simulation model results showed.

What we have actually observed in recent years is rather different: Apparently increased stringency of interdiction and other enforcement has been accompanied by a decline in the price of cocaine at every level of the market (Reuter and Kleiman, 1986). To account for this, we have developed a model of the market for smuggling services that incorporates the effect of smugglers learning, over time, how to reduce their risks and costs. This section presents a summary of this model and the results that it generates; a fuller account can be found in Cave and Reuter (1988).

The new model is not presented as a definitive account of the behavior of drug import markets; it is based on too many untestable assumptions about behavior to serve that function. Rather, it is intended to help illustrate the potential complexity of market responses to enforcement pressure and the necessity for a well-specified model if those responses are to be properly interpreted.

The model generates, under rather plausible assumptions, a supply curve that shifts out over time, i.e., at each successive time period smugglers are willing to provide more of their services, in aggregate, at a given price for those services. This reflects the accumulation of experience by dealers as a group. Thus prices may decline over time even though an increasing proportion of shipments are seized or an increasing number of smugglers and their agents are arrested. The results of SOAR and its variants may actually be too optimistic, since they fail to capture these experience effects.

This is not to discount the results of SOAR. That model deals with the medium-term (perhaps one-year) response of a population of smugglers that is either fully experienced or whose learning occurs over a longer period of time than that used in the simulations. The learning

is a long-run, secular effect that is layered over the adaptive response to changes in interdiction efforts.

The explicitly dynamic focus of the learning model generates a number of other interesting results, in addition to the shifting supply curve. Higher import prices, the primary goal for interdiction, are also the goal of experienced smugglers if they are few in number. High prices mean high profits for experienced smugglers. Also, high profits for experienced smugglers signal healthy return to investment in experience, which combines with high current prices to attract high-cost novice entrants. This entry will not depress market price below the high shut-down cost of the novices. Finally, the new entrants will dilute the interdiction risk faced by experienced smugglers and lower the latter's costs; this elevates their profits still further. Thus the model leads to closer and more accurate analysis of the fruits of interdiction. For example, it helps account for differences in the behavior of the cocaine and marijuana markets. The cocaine market has continued to expand rapidly, permitting the accumulation of a larger stock of experience, as described below. In contrast, the market for imported marijuana, particularly airborne and seaborne marijuana, has been declining in recent years, so any learning effects may be swamped by the increased risk associated with a smaller number of *target organizations.*

This model contrasts with assumptions implicit in most analyses. It also points to further complications in the analysis of interdiction effectiveness; changes over time in measures such as quantity seized, number arrested, etc., may turn out to be extremely weak indicators of the effectiveness of an interdiction effort as a drug control program. The model suggests more relevant criteria of interdiction success[1] and attempts to focus attention on the factors that should play a role in strategic decisionmaking.

We next discuss the "standard model" and outline the assumptions of the new model. This discussion is followed by a summary of the important results concerning market behavior generated by the model. The final section presents some policy consequences of those results.

Though the following discussion attempts to minimize the use of technical language, it constitutes a rather dense summary of a technical economic model. Readers who are interested primarily in policy issues may prefer to go directly to "Enforcement and Policy Implications" at the end of this section.

[1]We note though that these criteria will in general be more difficult to measure than the ones that are currently used.

THE STANDARD MODEL

Analyses of illegal markets in recent years have implicitly or explicitly used a model of competition and equilibrium carried over from conventional analyses of legal markets. The supply curve for illegal drugs is assumed to be a smoothly increasing function of price that shifts upward in response to increased law enforcement because all suppliers face increased risk as a consequence. Figure 7.1 presents that view.

In this model, all dealers need not be assumed to be alike in their response to heightened risk. However, it is necessary to assume that all dealers are affected by increased risk in that their unit costs rise. Since the costs of drug dealing are dominated by law-enforcement-imposed risks (directly or indirectly), this assumption seems reasonable. Figure 7.2 presents this component of the standard model.

If law enforcement does not also shift the demand curve,[2] this assumption implies that the price at which the market will clear (i.e., demand and supply will be equalized) will rise in response to increased law enforcement. Given a downward sloping but not perpendicular demand curve, the quantity sold will decline.

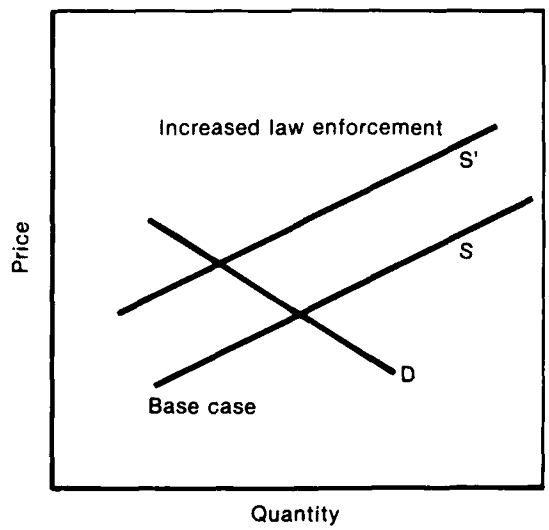

Fig. 7.1—Conventional static analysis

[2]That is likely to occur only when enforcement is aimed at the retail market, so that users face greater risk or delay in searching for a supplier.

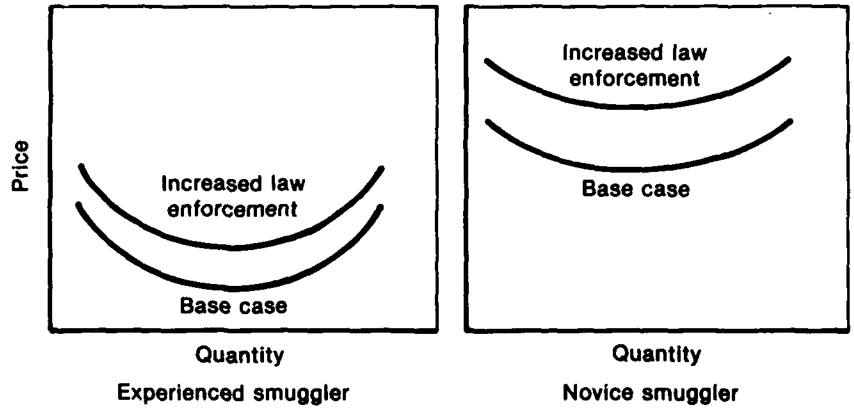

Fig. 7.2—Shifts in average cost induced by law enforcement

This result holds, whether or not one assumes competition on the supply side. If the market is monopolized, increased riskiness may reduce the "rents" (excess profits) of the monopolist, but the direction of the price and quantity effects will be unchanged. See Moore (1977) for an exposition of this point with respect to heroin markets.

AN ALTERNATIVE MODEL[3]

An alternative to the standard model focuses on differences among dealers. Some dealers are experienced, while others are novices. The risks to which experienced dealers are exposed may be very much lower than those facing novices. Since our interest is interdiction, we shall now refer to dealers as smugglers, though much of the analysis can be applied to all drug dealing.

Experienced smugglers, precisely because they have made a number of deals already without being incarcerated, are likely[4] to have learned how to lower the risk of their operations. For example, if prior shipments have succeeded, the smugglers will have better information about the trustworthiness of sellers, agents, and customers, as well as

[3]This model has its origins in a conjecture by Mark Kleiman at a project conference on May 13, 1986.

[4]No stronger statement is possible, since some smugglers will succeed simply by good luck, enforcement being a random process. Such smugglers may learn nothing from their experience. Our analysis requires only that some smugglers, not all smugglers, learn systematically from their experience.

about the risks associated with the various routes and modes of importation. Indeed, even if the shipments failed, the smugglers may have acquired valuable (but negative) information about the same matters, very much as Mark Twain suggested that he preferred river pilots who had frequently run aground—they know where the rocks are. To the extent that smugglers are aware of their own learning, they will perceive the riskiness of smuggling (for them) to have declined, compared with the risk associated with their initial shipment.

There are two potentially countervailing influences. Experienced smugglers are likely to be known by more persons. Since their risks rise with the number of persons cognizant of their participation in drug smuggling, *ceteris paribus*, experience may be risk-augmenting.[5] Experienced smugglers are also possibly more desirable targets to interdiction authorities because they may acquire a reputation as important smugglers. A novice smuggler, almost by definition, cannot be considered a high-value target.[6]

We shall assume throughout the analysis that experience is net risk-reducing. We believe that the reputational effect is a second-order one, in light of the orientation of interdiction to tactical intelligence and patrol efforts, neither of which targets shipments on the basis of a smuggler's past efforts.

The experience effect is unlikely to continue indefinitely. After, say, fifty shipments, there may be no further learning that leads to risk reduction. All this model requires is that experience sometimes reduces, but never increases, smuggler risk vis-à-vis less experienced smugglers and that the very experienced smuggler has significantly lower costs than the novice.

Now let us turn to assembling the components of the market analysis. The smuggler's average cost curve relates the cost per unit of drug delivered to the total quantity delivered in a given period. We expect it to have a U shape, i.e., per-unit costs decline as the quantity smuggled per month, say, increases, but they then increase again. The

[5]However, there are risk-controlling strategies that can mitigate this effect (see Reuter, 1983, Chap. 5). Moreover, reputation can be risk-reducing as well as risk-enhancing; the agents of smugglers with a reputation for contingent violence are less likely to inform on their employers.

[6]More precisely, a law enforcement official faced with a choice between an experienced and a novice smuggler should prefer the former. However, the choice between targets is rarely so simple; it is often implicit in the choice of interdiction technique or strategy, and it may be heavily resource-constrained. In addition, law enforcement agencies may face incentives that favor maximizing the rate of seizure or arrest, regardless of who is arrested. Novice smugglers caught with large quantities of drugs may be seen as significant smugglers, when instead they may belong to a large pool of small fish with big aspirations.

point of minimum unit smuggling cost is determined by prior experience levels, as discussed below.

Costs are measured in terms of quantity delivered per unit time. One smuggler may develop methods for moving 100 kilograms of cocaine per month in one shipment (by boat or private plane), while another may move the same quantity each month but in 20 separate 5-kilogram shipments (land smuggling over the Mexican border). Risks for the importer are likely to be determined by the number of customers and suppliers with whom he deals, which is a function of sales per month, rather than the number of shipments.

The phenomenon of cost reductions with experience (called "learning by doing") has been examined in a number of contexts. For example, it turns out to be an important explanation of the performance of firms in the airframe and other industries where repeating a task, or repeating working together, can make a group more efficient (see Rosen, 1972). It has even been the centerpiece of the strategic advice provided by a major consulting company (see Boston Consulting Group, 1972).

Implicit in the definition of the cost curve are choices of strategic variables such as shipment size, frequency, route, etc. These choices may vary with the total throughput desired, the experience level of the smuggler, and the law enforcement environment.

For example, the experienced smuggler may choose to invest in smaller shipments that have the effect of flooding interdiction resources. Since interdiction forces have high fixed costs per seizure (costs unrelated to the size of the shipment caught), their efficacy is proportional to the size of the average shipment; an experienced smuggler may be able to reduce the mean rate of seizure by strategic decisions about the size and frequency of shipments. In addition, a strategy of frequent small shipments directly reduces the variance of the delivered flow of drugs.

The suppliers in this model are smugglers facing different levels of risk. Novice smugglers have higher cost curves than do experienced smugglers. There may be discontinuities in the market supply curve; in particular, there is likely to be a discontinuity at the price level at which marginal smugglers[7] enter the market. The supply curve corresponding to this is given in Fig. 7.3.

A highly significant characteristic of this model is that experience can be quantity-specific. Experience in smuggling, say, 10 kilograms

[7]We assume that smugglers differ only with respect to experience. In particular, novice smugglers are all alike. This analytically simplifying assumption does not affect the basic results. We also assume that novice smugglers must enter at a positive minimum optimal scale.

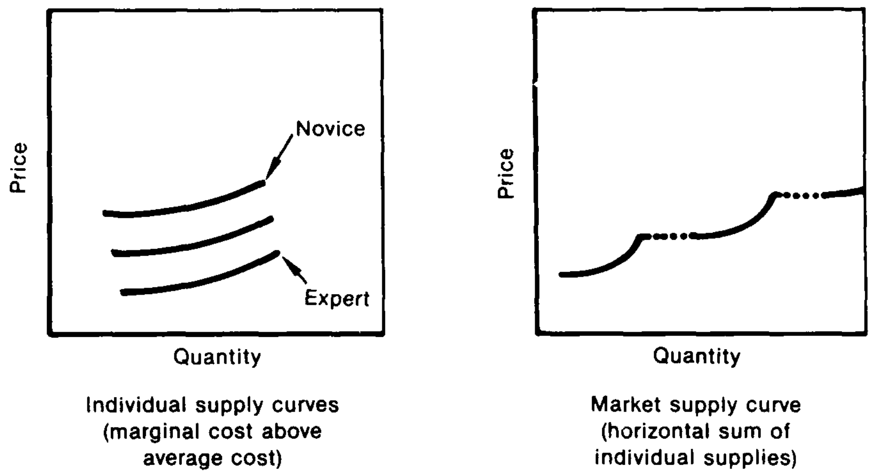

Fig. 7.3—Supply curve for a competitive market

per month significantly lowers costs for all quantities in the neighborhood of 10 kilograms per month but has little effect on the costs associated with much larger quantities per month. This reflects the fact that much of the risk reduction arises from transacting with a set of customers (high-level domestic dealers) who can themselves handle a certain quantity per month. Large increases in the smuggler's throughput force him to incur the risks of searching out additional customers; his advantage compared with a novice smuggler is then much reduced.

This incrementalism explains why there is room for novice smugglers, even though at any given monthly output, experienced smugglers have lower costs than novices.[8] Figure 7.4 illustrates this feature. There are only a limited number of experienced smugglers at any one time. If the price at which they are willing to supply the market demand is sufficiently high, some inefficient (novice) smugglers will be able to enter. This entry is more likely when the number of experienced smugglers is small or when the amounts demanded greatly exceed the amounts the smugglers are accustomed to supplying.

[8]The increase in costs at throughputs far below the smuggler's recent experience comes from the fact that his usual customers may be unwilling to deal with him if he cuts back sharply on the quantities he makes available to them each month.

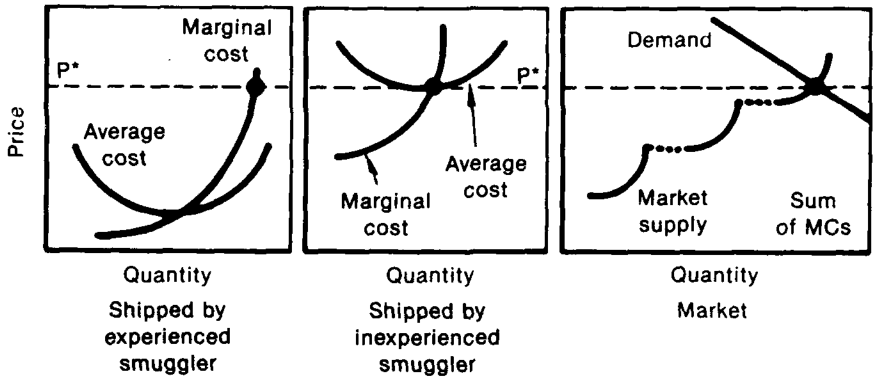

Fig. 7.4—Coexistence of inexperienced and experienced smugglers

EQUILIBRIUM AND INTERDICTION EFFECTS

This model suggests that the supply curve will shift out as the stock of experience increases. Individual smugglers (if they are not removed from the market) acquire experience and hence their costs become lower. If the market contains no novice smugglers and if the marginal smuggler in the market in period 2 is more experienced than the marginal smuggler in the market in period 1, then the market price, with competition, will be lower in period 2.[9]

This downward movement of price with constant interdiction severity is not inevitable; an interdiction program, either by design or by chance, might seize enough of the experienced smugglers that the total stock of experience will fall over time. But it is unlikely that interdiction will reduce the aggregate experience level of the market, because experience is risk-reducing, i.e., more experienced smugglers are less likely to get caught in a crackdown than are novices.

The demand curve for an addictive drug will generally shift out over time (other factors staying constant), because individual user demand curves will shift upwards; users become willing to pay more for a given quantity per unit time as they become addicted.[10] Thus the shift out of

[9]The market price of smugglers' services is determined by the cost of providing the last unit of the service that is actually consumed. Thus it is the marginal smuggler whose costs determine the market price.

[10]This is particularly true for "immature" markets, in which the amount used by each addict and the number of addicts are both increasing. In mature markets, demand may level off or even decline, particularly if the drug has unattractive long-term side effects which (1) reduce its attractiveness to potential new users, (2) kill off existing addicts, or even (3) reduce the work performance and hence the disposable income of long-term addicts.

the supply curve may not show up initially in the form of lower prices, because simultaneous increases in demand can lead to any direction of price change (see Fig. 7.5). Outward shifts in the supply curve unambiguously increase the quantity sold, *ceteris paribus*. Unfortunately, quantity sold is observed with a long lag and large measurement error; in the short run, the quantity seized, which is the most widely used indicator of the quantity shipped, provides no evidence (by itself) about total consumption.

At this point, it is appropriate to point out an important difference between the policy analyses of legal and illegal markets. In analyzing legal markets, we care only about the quantity sold: More is better than less (up to the competitive quantity), and profits are only a distributional issue. The analysis of drug markets takes account of quantity (less is better than more), but it must also consider profits.

Successful interdiction unambiguously reduces the quantity of drugs consumed, below the unimpeded competitive equilibrium value. The resulting allocation of economic surplus will depend on how the policy affects the costs of smugglers with different levels of experience. An interdiction policy that chiefly affects novices may preserve or enhance profits earned by experienced smugglers. If potential entrants recognize the correlation of profit and experience, they may rationally decide

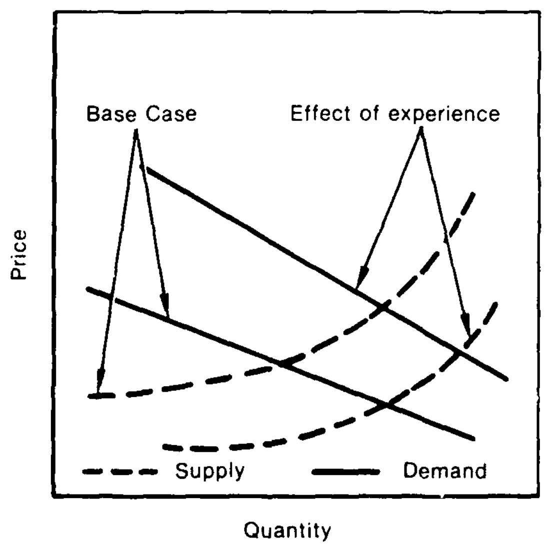

Fig. 7.5—Indeterminate direction of price changes when demand and supply shift

to enter even when their current unit cost exceeds the current market price, provided the present expected value of reduction in future cost attributable to current experience is sufficiently high. In markets for legal commodities, this is known as "investing in the learning curve."

A policy that places a heavier burden on inexperienced smugglers may tend to encourage entry and increase future supply. By contrast, an interdiction policy that targets experienced smugglers will reduce the perceived return to experience. If this is recognized by novices, it will discourage entry, leading to somewhat lower supplies in the future. Of course, the two types of policy will have different costs per unit reduction in current quantity. The point we are making is simply that the policy choice for a given resource level may require a tradeoff between reductions in current quantity and reductions in current profit levels for experienced smugglers.

A policy that targets experienced dealers may encourage them to dissipate their rents by investing in costly circumvention activities. The reduced return to experience, by discouraging entry of rational novices, may provide beneficial long-run supply reductions even if it has no impact on current price or quantity.

There is no reason to assume that increased law enforcement elevates risks equally across experience levels. For example, increased interdiction may raise the perceived risk for all smugglers by the same proportion of the existing level. Experienced smugglers who previously estimated the risk of capture at 10 percent would raise their estimate to 15 percent, while novice smugglers would raise their estimate from 20 percent to 30 percent.

This increase in the differential between the risks of the two groups might be the result of the experienced smuggler's superior ability to make adaptations to the new enforcement. For instance, if experienced smugglers purchase information from radar operators that helps lower the risk of their planes being sighted crossing the border, they will be less affected by the increased effectiveness of such surveillance. It is not necessary to assume that they can costlessly negate the increased stringency, only that their risks (costs) will be less affected than those of novice smugglers.

Under the assumptions of this model, different products of interdiction have potentially different effects. Seizures of drugs or assets affect estimates of costs associated with particular routes or modes. But the incarceration of an importer removes experiential capital from the system. The impact of such incarceration will depend on the experience of the smuggler incarcerated. The removal of a more experienced smuggler will have a greater impact on the supply curve than the removal of a less experienced smuggler.

We have assumed here that smugglers (i.e., the entrepreneurs) have the relevant cost-reducing experiential capital. At least some of this capital may in fact be held by their agents. Pilots with a sufficient knowledge of routes and the relevant evasive actions may capture some of the relevant risk-reducing learning; their removal will have an impact similar to that of the incarceration of smuggling principals.

The analysis also points to the multiple incentive of any importing cartel to keep prices high. Member risks are reduced by the presence of novice smugglers who represent the easy targets for interdiction agencies. In contrast to their legal counterparts, drug smuggling cartels want to encourage attempted, though not successful, entry. A small number of experienced smugglers who used their cost advantage to cut prices would face increased costs as a result, since the lower prices would deter potential entrants.

This suggests that the decline in cocaine import prices may be driven by changes in the structure of the market. Small numbers of competitors may have kept the price high in the late 1970s, both to maximize short-term profits and to induce novices to enter the market. Natural attrition among the experienced smugglers, combined with the increased experience of new entrants, gradually eroded that position during the 1980s.

A further implication is that law enforcement policies that disproportionately affect novice smugglers may actually stabilize the cartel of experienced smugglers by raising the costs of entry. This is particularly true if novices have smaller networks and are thus more likely to be incarcerated when their shipments are seized.

ENFORCEMENT AND POLICY IMPLICATIONS

The law enforcement variables in our model are highly simplified, but they suggest the likely effects of different strategies. Law enforcement cost pressure can be uniform across all active smugglers, or it may be adjusted to differentially affect experienced and inexperienced smugglers. In principle, technical means of border interdiction will place slightly more pressure on inexperienced smugglers, while strategies that involve more conventional police activity can direct attention to large and/or experienced smugglers. The law enforcement variables include one that reflects both experience and duration of activity, to model learning on the part of law enforcement officials.

The accumulation of such experiential capital is difficult to capture, because adaptation is somewhat cyclical in nature. As the smuggler modifies his methods in response to increased interdiction, law

enforcement officials will attempt to adapt to the new smuggling techniques. Unfortunately, adaptation on the part of the interdictor tends to lag behind the adaptations made by smugglers.

This view of smuggler learning and adaptation can be more generally applied to drug enforcement at all levels. There is a parallel between the border crossing "learning by doing" cycle and drug enforcement at the street level. Local police officials have described a specific situation where the formation of a new undercover task force began to increase arrests and convictions. After a period of 18 months, the dealers developed a complex system of lieutenants, holders, runners, and money men to insulate themselves from prosecution. It then took the police almost two years to identify and separate the components of the new network and adjust their own operations accordingly.

In computer simulations, described in detail in Cave and Reuter (1988), the set of active smugglers evolves over time in response to experience-induced cost changes. If learning is rapid, the market quickly becomes concentrated and sustains a price below the shutdown price of novice smugglers. If learning is slow, the set of active smugglers may increase, and a more competitive environment will prevail.

It is important to distinguish the two forces leading to an eventual fall in price. If learning is rapid, increased experience among the active smugglers leads to cost reductions which are passed on to the consumer by the forces of competition. If the pace of learning is slower, price reduction is achieved through entry. The difference is that per-smuggler rents are much higher in the latter situation.

The results are sensitive to a number of parameters, such as the correlation of enforcement and experience and assumptions about whether smugglers are price-takers or cooperative. We regard the model less as an accurate depiction of reality than as a way of demonstrating that the standard model is inadequate. Computer simulation can also serve to demonstrate the plausibility of the possibilities suggested by a more detailed analysis. So far, we have simulated each of the possibilities referred to above. Different patterns of law enforcement pressure can lead to higher or lower per-smuggler rents, more or less rapid entry, and even cyclical behavior of prices, quantities, and numbers of active smugglers.

If learning is indeed the central form of investment in smuggling, a major objective of interdiction must be to render such learning inefficient or to reduce the value of the acquired capital. More practically, this points (as did the SOAR results) to the importance of randomizing strategies to minimize the value of past experience. For example,

Coast Guard patrol allocations that vary a great deal at apparently unpredictable times will raise the perceived risk of experienced smugglers. Past successes in getting marine shipments of marijuana to south Florida will be seen to have little value in lowering the risk of future shipments.

At least two factors limit the value of this result. First, much of the experience capital may be related not to knowledge of law enforcement strategies but to the acquisition of a set of low-risk collaborators. A wholesaler to whom the smuggler has made five sales without being turned in to the authorities and without being defrauded financially represents an asset for that smuggler in terms of reduced risk. Similarly, experienced smugglers are more likely to know foreign (and even U.S.) officials whose cooperation can enable them to learn about interdiction strategy changes relatively quickly. Changes in interdiction strategies offer little opportunity to affect the value of such assets for the smuggling community.

Second, randomization is not costless to the interdiction agencies. Routines are followed at least in part because they represent efficient ways of using resources. Agents and equipment do not have to be moved around; they learn characteristics of the terrain and the profiles of the non-smuggling population. The benefits of randomization must be balanced against the cost of shifting resources.

The other significant policy conclusion is that evaluation of the effectiveness of interdiction must take into account the changing character of its target. In comparisons over time, whether of seizure rates or price differentials, an improving interdiction system, i.e., one that becomes increasingly efficient in its task, may well show (for some time) increasingly poor performance because of the dynamic nature of the smuggling market.

VIII. CONCLUSIONS AND POLICY ANALYSIS

Expenditures on interdiction have grown rapidly in recent years but no effort has been made to evaluate just what impact these expenditures have had on drug use in the United States. Current pressure to add substantial military resources to the interdiction program makes the lack of such an evaluation a serious problem.

This study has attempted to provide the framework and some of the analysis for such an evaluation. In this section, we use the results presented earlier to analyze the likely outcome of further military expenditures on drug interdiction. We first summarize our findings with respect to the impact of interdiction generally. Then the actual and potential roles of the military services in the interdiction effort are examined. Finally, we draw these strands together and assess the value of interdiction generally.

THE PROSPECTS FOR INTERDICTION

The central conclusion of this analysis is that interdiction probably cannot much further reduce the availability of cocaine and marijuana. However, there are some important differences between the two drugs. The conclusion is firmer with respect to cocaine than to marijuana. Moreover, the explanation for the conclusion differs between the two drugs, since domestic production is central for marijuana and irrelevant for cocaine.

This is not to say that interdiction can never be effective. A great deal depends on the nature of the targeted activity. Interdiction aimed at the smuggling of bulky commodities from very distant locations will probably succeed; the terms of exchange, so to speak, favor the interdictors. Targets are conspicuous, are in sight for a long period, and have few locations for easy unloading. There may be relatively few similar-looking large vessels coming along the same routes, making it easy to have a high inspection rate, and inspection is likely to be successful. If, for example, the United States wished to prevent the smuggling of Japanese-manufactured automobiles, it could probably succeed with relatively little effort. Similarly, it is not difficult to restrict the flow of Thai marijuana to the United States.[1]

[1]We do not mean to imply that it would be easy to eliminate the import of Thai marijuana, but only that this traffic is far more vulnerable than, for example, marijuana com-

Cocaine

Cocaine represents almost the opposite kind of target. The good is produced in locations that are fairly close to the continental United States. At least it does not have to cross long water routes to reach this country. It is slight in bulk; a single cargo plane, fully loaded, could supply the nation's current demand for a year. The demand curve for the good is such that shipment in small units will still allow for adequate profits for the smugglers and domestic distributors.

Moreover, there are numerous adaptations available to cocaine smugglers that enhance their chances of avoiding capture of drugs or agents. They may use transportation means that are inconspicuous, i.e., are very similar to many other vessels (using the term broadly to cover all forms of transportation) traveling along the same paths. The EPIC list of "lookouts," with its approximately 17,000 seagoing vessels and 20,000 planes, is evidence of the large number of potential means of bringing in the drug.

It is likely too that the smugglers are more flexible than the interdiction agencies. They do not have the kinds of organizational rules and requirements that inhibit government agencies' rapid adaptation to new smuggling methods.

Smugglers are also, in some senses, the richer of the two opponents. Increased costs can be passed on to final users with little loss of market, i.e., the final demand for cocaine is very inelastic with respect to the costs of importation.[2] Where the interdiction agencies must work with fixed budgets and relatively slow procurement procedures, smugglers may acquire new equipment and personnel as rapidly as the market permits. The total funds available to smugglers, as measured by total receipts for smuggling, are higher than those commanded by the interdiction agencies.

An important asset for each side is information about the tactics of the other. Sometimes the government procures such information with money; more often, it does so by dropping charges against those it catches. Smugglers occasionally procure information about interdiction agency activities through threats of violence; more often, they do so by paying low-level government personnel, who can put large interdiction operations at risk with a relatively low probability of being detected.

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ing across the Mexican border. If the Mexican border were closed, it is unlikely that similar quantities could then come in from Thailand.

[2]That is, the market demand curve is inelastic with respect to the import price. Each smuggler faces a quite elastic supply curve, given the evidence concerning low price dispersion presented in Appendix A.

The advantages are not all with the smugglers; interdiction agencies may be more successful than smugglers at recruiting informants. The government can increase its capacity to recruit informants by raising the penalties faced by detected participants; the pilot facing a ten-year sentence is more likely to turn on his former employer than is the pilot facing only a five-year sentence. Tough sentences have even generated mafioso informants. The government incurs few risks in making offers to potential informants; smugglers must always be concerned that their offers will generate double agents and/or arrests for attempted bribery.

At the tactical level, there are many methods for negating increased interdiction efforts. For example, pursuit resources can easily be drained away. A smuggler who hires five look-alike planes and sends four of them through empty, with the fifth (in a random order) containing the drug, can dramatically lower the risk of effective pursuit, at a relatively modest cost. Air smuggling, which involves dropping drugs at remote sites, followed by return to Mexico, can make the probability of seizure of the drugs extremely low.

Smugglers who file flight plans for one airport and then file amended flight plans to another airport after crossing the border can greatly lower the probability of being identified as smugglers. We have not even investigated the use of drones (pilotless vehicles), a technology not far in the future, which might simultaneously crowd the skies and avoid putting any pilot at risk.

We also must note the lessons derived from SOAR. If interdiction efforts cannot raise the interception probabilities on the majority of routes of smuggling, increased interdiction can have only a modest effect on the costs of bringing in cocaine. If interdictors can move their resources rapidly and inconspicuously, the conclusions are less pessimistic, but it is not clear that, given bureaucratic and personnel restrictions, rapid changes can be made in interdiction allocations among smuggling routes.

Marijuana

These arguments apply less strongly for marijuana, the smugglers of which are handicapped by the relative bulk of the drug. The total weight of marijuana imports is probably fifty times that of cocaine imports; the disproportion is even greater in terms of volume, the more relevant consideration for smugglers. An interdiction system that requires the importers to bring marijuana in 250-kilogram bundles, with significant transportation costs, can raise the imported price of marijuana substantially and thus cause a reduction in total import demand. The very much larger proportional markup of marijuana

prices from export to import is indicative of this greater interdiction impact.[3] Thus it is not surprising that the SOAR results showed significantly more impact of increased interdiction severity, although we were not able to formally include a domestic production sector in that model.

Nevertheless, we are pessimistic about the possibility of reducing marijuana consumption much further through interdiction. Two distinctive features of the marijuana business are particularly important here: domestic production and Mexican imports.

Domestic production has become a highly significant source of U.S. consumption. It seems likely that increases in import costs have led to this rise in the domestic marijuana crop. Though domestic enforcement in the past two years may have struck effectively at the more conspicuous producers, adaptations by domestic growers can, in the long run, significantly lower the effectiveness of these efforts; these adaptations include shifts to less-conspicuous production modes (e.g., greenhouses, interior plants) and production of higher-potency plants. The latter adaptation reduces the acreage needed to produce enough marijuana for total consumption. The smaller the acreage needed, the less effective enforcement against production is likely to be.

The second factor that reduces the impact of marijuana interdiction is the availability of Mexican-source marijuana. Imports from Mexico are difficult to interdict because their time of vulnerability to agencies is so brief. A ship coming from Colombia is at risk for days; even a plane coming directly from Colombia is a trackable target for some hours. In contrast, a plane coming across the Mexican border is at risk for a very short period of time. Smugglers also may use the land border more easily than those importing from more distant locations, who must incur the additional costs of getting the drug into Mexico initially. The land route appears to be the one least subject to effective interdiction pressure.

The spraying of paraquat and the growth of higher-quality Colombian marijuana reduced Mexican exports, and probably production, in the mid-1970s. It appears, however, that there has been a dramatic increase in Mexican production, as evidenced by a single seizure of some 1,900 tons in early 1985. Official estimates now assign 22 percent of imported marijuana to Mexican sources, compared with only 3 percent in 1978.

No explanation for this resurgence has been provided; we suggest that it may represent a response to the increasingly stringent maritime

[3]Transportation costs are higher per dollar of export price for marijuana, but this cannot account for much of the difference.

interdiction that has raised the cost of importing the drug from Colombia. There is also anecdotal information that Mexican growers are now producing marijuana of significantly higher quality than that produced in pre-paraquat days. The collapse of the Mexican economy since 1982 may also play some role in shifting resources there into marijuana production.

An additional reason, apart from the negation of interdiction efforts, for being concerned with the increase in the share of marijuana coming from domestic and Mexican sources is that these sources generate smaller and less vulnerable distribution networks than do large-scale imports. The very large shipments that came in from Colombia, particularly in the late 1970s (probably the heyday of that traffic), required large unloading organizations which turned out to be relatively vulnerable to enforcement (see, e.g., Warner, 1986). Domestic production, precisely because it tends to be localized (cultivation has been found in all 50 states) and small in scale, permits relatively small distribution chains, which significantly complicates the task for domestic enforcement agencies.

Mexican-source marijuana also permits smaller-scale importation without much increase in per-unit transportation costs. The drug may cross the border in relatively small bundles (100 pounds) and does not generate the large-scale distribution networks of the 10-ton shipments from Colombia. It is not as decentralized as domestic production, but again, it presents a smaller target for enforcement.

MEASURES OF EFFECTIVENESS

The existing analyses of interdiction use very simple measures of effectiveness and fail to take account of smuggling adaptation. We believe that, incomplete as our own analysis is, it does point to the importance of both these issues.

The effectiveness of interdiction in reducing the availability of cocaine and marijuana to U.S. users—its major goal—is poorly measured by quantities seized or even the share of imports seized. We have made this point throughout the report, but given the continued attention paid to these measures, we have summarized here the kinds of errors that can be induced by focusing on seizure data.

The quantity seized is a function of many factors, including the quantity shipped, the intensity of interdiction, and the replacement cost of the drug. The quantity of marijuana seized has declined by about 50 percent in the last five years, while that for cocaine has risen tenfold in the same period. As measured by changes in quantities

seized, the cocaine program would appear to be successful, while the marijuana program has had declining impact. In fact, other evidence indicates that quite the opposite is true.

The rise in the quantity of cocaine seized is probably explained by the growth in the quantity shipped and the declining export price of the drug. The seizure figure may also reflect the influx of less experienced smugglers, as the returns to participation have become clearer—a result suggested by the analysis of Section VII. Interdiction's contribution to the price of cocaine (and hence to its consumption) may actually have declined in the period.

On the other hand, the quantity of marijuana seized may have declined because less is consumed (partly the result of shifts in taste, as revealed in the High School Senior Survey), more is produced in Mexico and domestically, and the current crops are of higher potency. The last two factors are probably the result of increasingly effective interdiction. Increased potency reduces the amount of marijuana that needs to be shipped, since the demand is not for the plant itself, but for the THC it contains. Domestic production is a response to a rise in the import price. It may turn out, unfortunately, that the United States has at last managed (rather expensively) to provide effective tariff protection for one industry: marijuana production.

Imperfect though it is, we believe that the price related criterion, i.e., the difference between import and export prices for a drug, provides a much better measure of the impact of the interdiction effort. It cannot be applied to the performance of individual interdiction units, but it can provide high-level policymakers a much better measure of the contribution of interdiction expenditures toward the reduction of drug use in the United States.

THE DEPARTMENT OF DEFENSE AS AN INTERDICTION AGENCY

Despite its increasing expenditures in support of drug interdiction, the DoD remains a support agency rather than a primary interdiction agency. Its activities can enhance those of the primary agencies (the Coast Guard, the Customs Service, and the INS), but they cannot substitute for them.

One explanation for this is the existence of legal constraints. Even with the recent relaxation of the Posse Comitatus Act, autonomous interdiction activities by military personnel are still subject to numerous restrictions. Most significantly, military personnel do not have arrest powers. As a matter of historical doctrine, there is

considerable uneasiness about the use of the military for civilian police functions, and it seems unlikely that this legal restriction will be relaxed in the near future.

Another problem arises from the fact that interdiction is a secondary activity for military units. In some cases, there is a close fit between military and drug interdiction missions, for example, in the Army training exercises at Fort Huachuca. But in other cases, such as the use of AWACS, there is some conflict between the primary military mission and drug interdiction.

THE RELATIONSHIP BETWEEN MILITARY SUPPORT AND DRUG INTERDICTION

Military support is largely responsive. Individual agencies make requests of the military for resources, the vast majority of which have, so far, been honored. Does that suggest that enough military resources are available for interdiction?

If it is accepted that the proper military role is to support the activities of other agencies, the answer is apparently positive. Additional resources that are not used by the agencies will be relatively unproductive in that use. Dedicating military interception aircraft to drug interdiction has little value if the agencies cannot generate enough targets to make use of them. Having military aircraft flying surveillance missions when there are no interception aircraft available to respond to the additional sightings generated by the missions is also unlikely to be a productive use of resources.[4]

On the other hand, the volume of requests from interdiction agencies may not be a perfect measure of the utility of military resources. Such requests are made when the agency has a need *and knows that resources are likely to be available.* The high response rate to interdiction agency requests may simply mean that these agencies are aware that there is relatively little available from the services. There may be a great deal of informal negotiation before formal requests are made.

If, however, the military services aggressively "advertise" the availability of their resources, they may generate more requests, which they will indeed be able to satisfy. The reluctance of the military, until now, to provide a listing of relevant capabilities to the interdiction agencies suggests that they are aware that such a list might indeed generate additional requests. The requirement of the 1986 Omnibus Drug Control Act for the preparation of an inventory of capabilities and a

[4]There may, however, be some value in the information that such flights provide concerning the distribution of traffic in particular areas at particular times.

plan for their utilization will help determine just how responsive the interdiction agencies are to knowledge of what is available.

Another limitation of military interdiction capabilities also deserves mention. The interdiction agency data concerning the performance of their resources show extremely low rates of successful identification. The Coast Guard success rate with boardings (see Section III) is only 4 percent, largely because drug vessels are so lacking in distinguishing features. When prior intelligence has indicated the possibility that a vessel was carrying drugs, the fraction of successful boardings is higher, but it is still only about 12 percent.

If, as appears to be the case for marine interdiction, the primary resource offered by the military services is a greater number of targets, the Coast Guard experience suggests that it may not be possible to accomplish much more than is currently being done. At present, the Coast Guard boards a relatively small percentage of the vessels it identifies, which in turn is a small percentage of the total it detects. Adding modestly to the capability to detect and identify more vessels (which may be all that can be accomplished with additional Navy assets) is not likely to greatly increase the number of seizures.

We believe that the critical issue is whether the military can appreciably increase the effectiveness of interdiction at the Mexican border. The border is presently very vulnerable to both land and air smuggling. The weakness of the air interdiction effort has been the subject of considerable concern, and a substantial part of the military expenditures in fiscal year 1987 are earmarked for improving this effort.

The tethered aerostats being acquired this fiscal year may significantly raise the number of sightings of small planes crossing the border. But it is not at all clear that this will increase the success of the interdiction program, because the probability of correctly identifying smugglers may be low and the air pursuit system will still have very limited capacity.

The San Diego Air Branch of the Customs Service currently limits itself to pursuit of intelligence-identified targets. The agency lacks adequate means of sorting among the many radar sightings to identify high-probability targets. Better surveillance will significantly augment these efforts only if (1) many current smugglers are in fact avoiding radar sighting, and (2) they are unable to effectively blend in with the traffic once they learn that the previously unsurveilled routes are now covered by radar. Given the number of methods for blending into legitimate traffic in high-density areas (such as the area around San Diego), it is difficult to be optimistic about the prospects for better surveillance having a major impact.

THE VALUE OF INTERDICTION

The rather pessimistic tone of this report should not be interpreted to mean that interdiction is useless or that the military services should not participate. Interdiction does have an impact on drug use, and military support can increase that impact. The study does, however, point to the limits both of interdiction efforts as a method for reducing cocaine and marijuana use in the United States, and of the *potential* contribution of the military services to increasing the efficacy of interdiction, however measured.

We note again that interdiction has objectives other than the reduction of drug use. For example, it provides a degree of equity in drug enforcement. Those associated with the higher end of the drug traffic should be at some risk from enforcement, and interdiction appears to provide such risk, though it is mainly borne by the agents of the higher-level entrepreneurs.

Interdiction is also intended to signal other countries, in the most visible way possible, that the United States takes drug importation seriously. Given the general belief that source countries, and even other major consuming countries, can help in reducing U.S. consumption, such a signal is potentially important.

But most important, pessimism about the ability of additional interdiction resources to reduce cocaine consumption by more than, say, 5 percent compared with its current level does not necessarily imply that less interdiction effort is justified. To address that issue, we now turn to the question of how one values the benefits of reduced drug consumption.

MEASURING THE BENEFITS OF DRUG ENFORCEMENT

The social costs of drug consumption in 1983 were estimated at approximately $60 billion (Harwood et al., 1984). That calculation includes costs arising from the treatment of drug abusers, reduction in the amount of labor available, costs of law enforcement (including imprisonment), etc. Some items not included in this estimate, however, are arguably very important, e.g., the decline in housing values arising from the elevated crime rates produced by heroin use.

The $60 billion estimate is very rough, but for our purposes, all that matters is that the number is in the tens of billions of dollars rather than merely billions of dollars. In the remainder of this section, we shall work with a $60 billion figure, but the arguments should hold whether the right number is $25 billion or $75 billion.

How much would the social cost of drug use be reduced if more effective interdiction reduced total consumption of cocaine by 5 percent? This type of calculation has been carried out only in the context of valuing the effectiveness of drug treatment programs.

The problem is complicated by time-specific factors. For example, the AIDS virus is widely transmitted by intravenous drug abuse, mostly through the sharing of needles by heroin users. If heroin use ended tomorrow, the nation would still face an enormous future bill as a result of the heroin abuse of previous years. On the other hand, continued heroin use, given heightened awareness of the risks of needle sharing, may not much increase the total AIDS bill (in the broadest social cost sense). In summary, calculating the costs of past drug abuse may not be a good basis for estimating the value of reductions in the future.

Moreover, though most chronic drug abusers use several drugs, the value of reduced drug consumption is drug specific. There is abundant evidence that heroin use is criminogenic; those who use heroin are much more criminally active when using than when abstinent. There is no evidence that marijuana use leads to crime, except that heavy marijuana use is strongly correlated with later use of more criminogenic drugs such as heroin. Reducing heroin consumption by 5 percent thus would have a very different value from reducing marijuana consumption by the same percent.

Estimates of the value of reductions in drug consumption are useful, for two reasons: (1) to determine the how much society should spend on drug control strategies, and (2) to determine whether resources within the drug control budget are being properly allocated. If drug abuse imposes costs of tens of billions, then spending a few billion is justified; if the social costs are only of the order of $5 billion rather than $50 billion, there would be more question about it. But unless current expenditures are really ineffective, the amounts being spent at the moment are clearly justified.

As for the second motivation for obtaining this measure, money is a useful metric for making comparisons. It would be desirable to be able to assert that an additional $100 million of interdiction will produce more social benefit than $100 million spent on, say, domestic enforcement; monetarizing benefits is a way of facilitating such comparisons.

We simply cannot say whether too much is being spent on interdiction relative to other programs. There are no serious estimates of what an additional $100 million in treatment expenditures would do to the level of illicit drug use. A close look at the interdiction program has not yielded much optimism about what can be achieved with increased expenditures there, but it may well be that a closer look at the other

drug policy elements would yield similar pessimism. This analysis is only part of what is needed to determine the appropriate allocation of the drug budget.

Appendix A

THE EFFECTS OF INTERDICTION ON DRUG EXPORTS

Donald Putnam Henry

OVERVIEW

Interdiction unambiguously raises the price and reduces the quantity of drugs imported into the United States, at least in the short run. Less certain is the effect of interdiction on prices and supplies in the source countries. Models of (almost) equal plausibility lead to opposite results: increased prices or reduced prices, greater supply or curtailed supply.

This appendix formally describes the conditions that determine which of these results is correct. The price and supply of drugs in source countries, while not as important to U.S. policymakers as the market in this country, is nevertheless of some interest. Lower export prices for drugs may impose economic hardships on supplier nations, while higher prices and increased involvement in drug trafficking may be socially corrupting and politically destabilizing. No judgment is made here about the preferred outcome from the U.S. point of view, or about which model is correct; in fact, different models may apply for different drugs. We simply present an abstract set of conditions that determines the outcome. Too little is known about many of the parameters in the drug markets to produce more concrete results.[1]

THE PROCESS

The world of drug producers, processors, traffickers, and users is complex and surreptitious. However, the aspects of the market that are important in this analysis can be captured in a simple model: Farmers (or other types of producers or processors) create drugs and introduce them into the market. Middlemen, including smugglers, couriers, wholesalers, and pushers, obtain drugs from farmers and deliver them to users, who finally consume the drugs. A person might

[1]Specifically, little is known about the price elasticity of supply for drugs by growers.

easily fall into more than one of these categories, but that is not important here.

Interdiction directly affects middlemen. Some of the drugs that are shipped do not arrive, creating a loss for them, and other penalties beyond seizure may also be incurred.[2] Middlemen, in equilibrium, will charge a margin large enough to compensate them for seized drugs as well as for other costs and risks of trafficking.

A SIMPLE MODEL

A very simple model sheds some light on how interdiction affects drug markets. In this model, drugs are exchanged costlessly between the farmers and users, except for some fraction i of drugs introduced into the market that are interdicted. Mathematically, the variables are:

D_u = demand for drugs by users
S_f = supply of drugs from farmers
P_u = price paid by users
P_f = price paid to farmers
i = rate of interdiction

The behavioral relationships are:

$D_u = D\ (P_u)$, user demand for drugs depends on user price

$S_f = S\ (P_f)$, farmer supply of drugs depends on farm price

The equilibrium conditions are:

$D_u = S_f\ (1 - i)$, user demand equals farmer supply less interdictions

$P_u = P_f\ /(1 - i)$, user price exceeds farm price to cover interdictions

What will happen to the market when the interdiction rate is changed? Short-term effects might disrupt the market in a number of ways, but we examine the new market equilibrium rather than the road

[2]These penalties include jail time, fines, seizure of transportation equipment, seizure of other assets that are deemed the reward of trafficking, greater variability of income, discovery by the authorities, and public embarrassment.

to that equilibrium. The quantity equilibrium condition can be totally differentiated:

$$D_u(P_u) = S(P_f)\,(1 - i)$$

$$\frac{\partial D_u(P_u)}{\partial i} = \frac{\partial[\,S\,(P_f)\,(1 - i)\,]}{\partial i}$$

$$\frac{\partial D_u}{\partial P}\,\frac{\partial P_u}{\partial i} = \left[\frac{\partial S_f}{\partial P_f}\,\frac{\partial P_f}{\partial i}\right](1 - i) - S_f$$

but

$$P_f = P_u\,(1 - i)$$

and

$$\frac{\partial P_u}{\partial i} = \frac{\partial P_u}{\partial i}\,(1 - i) - P_u$$

so

$$\frac{\partial D_u}{\partial P}\,\frac{\partial P_u}{\partial i} = \frac{\partial S_f}{\partial P_f}\left[\frac{\partial P_u}{\partial i}\,(1 - i) - P_u\right](1 - i) - S_f$$

Collecting terms, this expression becomes

$$\frac{\partial P_u}{\partial i}\left[\frac{\partial D_u}{\partial P_u} - \frac{\partial S_f}{\partial P_f}\,(1 - i)^2\right] = -P_u\frac{\partial S_f}{\partial P_f}\,(1 - i) - S_f$$

This expression can be multiplied by

$\dfrac{P_u}{D_u}$ which is equal to $\dfrac{P_f}{S_f\,(1 - i)^2}$ which is equal to $\dfrac{P_u}{S_f\,(1 - i)}$

producing

$$\frac{\partial P_u}{\partial i}\left[\frac{\partial D_u}{\partial P_u}\frac{P_u}{D_u} - \frac{\partial S_f}{\partial P_f}\frac{P_f(1-i)^2}{S_f(1-i)^2}\right] =$$

$$-P_u\left[\frac{\partial S_f}{\partial P_f}\frac{(1-i)P_f}{(1-i)^2 S_f} - \frac{S_f P_u}{S_f(1-i)}\right]$$

The price elasticities of supply and demand appear often in this expression, and many terms cancel, so it can be simplified to

$$\frac{\partial P_u}{\partial i}(\epsilon_d - \epsilon_s) = \frac{-P_u\,\epsilon_s}{(1-i)} - \frac{P_u}{(1-i)}$$

or

$$\frac{\partial P_u}{\partial i} = \frac{-P_u(\epsilon_s + 1)}{(1-i)(\epsilon_d - \epsilon_s)}$$

The price elasticity of supply of drugs and the user price of drugs are likely to be positive, the price elasticity of demand for drugs is likely to be negative, and the interdiction rate is likely to be somewhere between zero and one. Consequently, the user price of drugs will always rise as the interdiction rate increases, and the domestic demand for and use of drugs will always fall:

$$\frac{\partial P_u}{\partial i} > 0 \qquad \frac{\partial D_u}{\partial i} < 0$$

Using an expression derived above,

$$\frac{\partial P_f}{\partial i} = \frac{\partial P_u}{\partial i}(1-i) - P_u$$

$$\frac{\partial P_f}{\partial i} = \frac{-P_u(\epsilon_s + 1)(1-i)}{(1-i)(\epsilon_d - \epsilon_s)} - P_u$$

$$\frac{\partial P_f}{\partial i} = \frac{-P_u(\epsilon_s + 1) - P_u(\epsilon_d - \epsilon_s)}{(\epsilon_d - \epsilon_s)}$$

$$\frac{\partial P_f}{\partial i} = \frac{-P_u(1 + \epsilon_d)}{(\epsilon_d - \epsilon_s)}$$

When will farm prices rise? The above expression indicates that farm prices will rise when demand for drugs is inelastic, i.e., when $\epsilon > -1$. Does this make sense intuitively? The farm price of drugs will rise only if the quantity demanded at the farm, before interdiction, increases. A 1 percent rise in the interdiction rate will initially reduce user supplies by 1 percent and increase user price by 1 percent to cover increased lost shipments. If demand is inelastic, then by definition, a 1 percent rise in price will reduce demand by less than 1 percent. Equilibrium will be restored in the market only when user prices rise by more than 1 percent and the amount supplied by farmers increases somewhat.

In the simple model, interdiction will increase user prices and reduce user demand. Whether farm prices rise or fall depends only on the demand elasticity for drugs with inelastic demand yielding higher prices. The size of this rise in price depends on the elasticities of both supply and demand.

A LESS SIMPLE MODEL

A major problem with the simple model described above is that it largely ignores the middlemen between farmers and users. They collect a markup in the simplified model, but it is only enough to pay for the goods that are lost through interdiction. The middleman margin will in fact be much greater than this. Middlemen need to be compensated for their expenses in transporting and distributing drugs and for the risks of other penalties they face. Building on the simple model, a more complex model is developed below that includes compensation for middlemen. The variables are:

D_u = demand for drugs by users
S_f = supply of drugs from farmers
P_u = price paid by users
P_f = price paid to farmers
P_m = middleman margin
i = rate of interdiction

The behavioral relationships are:

$D_u = D(P_u)$, user demand for drugs depends on user price

$S_f = S(P_f)$, farmer supply of drugs depends on farm price

$P_m = P_m(i)$, middleman margin depends on interdiction rate

The equilibrium conditions are:

$D_u = S_f(1 - i)$, user demand equals farmer supply less interdictions

$P_u = P_f / (1 - i) + P_m$, user price exceeds farm price to cover interdictions plus middleman margin

What happens in this market when interdiction efforts increase? Again, in equilibrium, user demand will be equal to farmer supply less interdiction. This equilibrium condition can be differentiated:

$$D_u(P_u) = S(P_f)(1 - i)$$

$$\frac{\partial D_u(P_u)}{\partial i} = \frac{\partial[S(P_f)(1 - i)]}{\partial i}$$

$$\frac{\partial D_u}{\partial P} \frac{\partial P_u}{\partial i} = \left[\frac{\partial S_f}{\partial P_f} \frac{\partial P_f}{\partial i}\right](1 - i) - S_f$$

but

$$P_f = (P_u - P_m)(1 - i)$$

and

$$\frac{\partial P_f}{\partial i} = \left[\frac{\partial P_u}{\partial i} - \frac{\partial P_m}{\partial i}\right](1 - i) - P_u + P_m$$

so

$$\frac{\partial D_u}{\partial P_u}\frac{\partial P_u}{\partial i} = \frac{\partial S_f}{\partial P_f}(1 - i)\left[\left(\frac{\partial P_u}{\partial i} - \frac{\partial P_m}{\partial i}\right)(1 - i) - P_u + P_m\right] - S_f$$

Terms in the above expression can be collected to yield

$$\frac{\partial P_u}{\partial i}\left[\frac{\partial D_u}{\partial P_u} - \frac{\partial S_f}{\partial P_f}(1 - i)^2\right] =$$

$$\frac{-\partial S_f}{\partial P_f}\left[(1 - i)^2\frac{\partial P_m}{\partial i} + (P_u - P_m)(1 - i)\right] - S_f$$

This whole expression can then be multiplied by

$$\frac{P_u}{D_u} \text{ which is equal to } \frac{P_f}{S_f(1 - i)^2} \text{ which is equal to } \frac{P_u}{S_f(1 - i)}$$

producing

$$\frac{\partial P_u}{\partial i}\left[\frac{\partial D_u}{\partial P_u}\frac{P_u}{D_u} - \frac{\partial S_f}{\partial P_f}\frac{P_f(1 - i)^2}{S_f(1 - i)^2}\right] =$$

$$\frac{-\partial S_f}{\partial P_f}\frac{P_f}{S_f(1 - i)^2}\left[(1 - i)^2\frac{\partial P_m}{\partial i} + (P_u - P_m)(1 - i)\right]$$

$$- \frac{S_f P_u}{S_f(1 - i)}$$

The elasticities of demand and supply appear regularly, so

$$\frac{\partial P_u}{\partial i}(\epsilon_d - \epsilon_s) = \frac{-\epsilon_s}{(1 - i)}\left[(1 - i)\frac{\partial P_m}{\partial i} + P_u - P_m\right] - \frac{P_u}{(1 - i)}$$

And the change in the user price as the interdiction rate changes can be expressed as

$$\frac{\partial P_u}{\partial i} = \frac{-\epsilon_s (P_u - P_m) - P_u - \epsilon_s(1 - i)(\partial P_m / \partial i)}{(1 - i)(\epsilon_d - \epsilon_s)}$$

If the price elasticity of supply is positive, the price elasticity of demand negative, the interdiction rate between zero and one, and the change in middleman margin with respect to the interdiction rate positive, then a change in the interdiction rate will always lead, as expected, to an increase in user prices of drugs.

But what happens to the farm price? From above, the change in the farm price as the interdiction rate changes is

$$\frac{\partial P_f}{\partial i} = \left[\frac{\partial P_u}{\partial i} - \frac{\partial P_m}{\partial i} \right] (1 - i) - P_u - P_m$$

The change in the user price can be substituted here:

$$\frac{\partial P_f}{\partial i} = \left[\frac{-\epsilon_s (P_u - P_m) - P_u - \epsilon_s (1 - i)(\partial P_m / \partial i)}{(1 - i)(\epsilon_d - \epsilon_s)} - \frac{\partial P_m}{\partial i} \right]$$

$$\times (1 - i) - P_u + P_m$$

Collecting terms, this expression reduces to

$$\frac{\partial P_f}{\partial i} = \frac{-\epsilon_d (P_u - P_m) - P_u - \epsilon_d (1 - i)(\partial P_m / \partial i)}{\epsilon_d - \epsilon_s}$$

This can be rewritten as

$$\frac{\partial P_f}{\partial i} = \frac{-P_u (\epsilon_d + 1)}{\epsilon_d - \epsilon_s} + \frac{\epsilon_d P_m}{\epsilon_d - \epsilon_s} - \frac{\epsilon_d (1 - i)(\partial P_m / \partial i)}{\epsilon_d - \epsilon_s}$$

The first term in this expression is the same as in the simple model. The second term is always positive and depends o the size of the middleman margin. The higher this margin, the more likely prices are to rise. This is logical: If the middleman margin is large, then even if farm prices must rise greatly to draw out enough new production, user

prices might rise by only a small amount. Thus, even if user demand is elastic with respect to prices, user demand might not be elastic with respect to farm prices. The third term, always negative, incorporates the added margin that middlemen will want as the interdiction rate rises. This added margin will reduce user demand and, ultimately, farm prices.

CONCLUSIONS

A rise in the interdiction rate will, absent freak economic behavior, lead to a rise in user prices and consequently a decline in consumption, in the short run. Farm prices (and hence farm production) may either rise or fall. In a simple model where middlemen collect a margin only large enough to pay for seized goods, farm prices will rise if demand for drugs is inelastic, and they will fall if demand is elastic. Where (realistically) middlemen require a larger margin, and this margin depends on the interdiction rate, the picture becomes cloudy. The margin buffers (in percentage terms) users from large changes in farm price. This might make even a fairly elastic demand by users appear inelastic at the farm. Offsetting this effect is the sensitivity of the margin to the interdiction rate. This sensitivity amplifies the effect of the lost goods on user prices.

Appendix B

ANALYSIS OF WHOLESALE COCAINE PRICE DATA

William Lisowski

Analysis of wholesale cocaine price data supplied by the DEA supports the hypothesis that the data were generated by a market process in operation. Subject to the caveats given below, it appears that

- Prices are consistently lower for larger transactions.
- Prices are consistently lower in Florida than in the rest of the country.
- Prices in the New York metropolitan area are consistently above those in Florida but below those in the rest of the country.
- Over 1985 and the first three quarters of 1986, there was a downward trend in prices, which holds across subsets of the data as well.
- Variability in prices is reasonably small and is generally reduced when the data are disaggregated by transaction size or location.

Each of these findings is consistent with the assumption that the data are observations of a functioning market. Beyond spreading a fixed transaction cost over more units, large transactions generally represent an earlier stage in the distribution process—one nearer the producer, with less intermediate markup. Florida, as the principal point of entry of cocaine, and New York, as a large retail market, should each have larger supplies and increased competition among wholesalers. The downward trend in prices over time is not in and of itself an indication of a market in operation, but the consistency of this trend across locations and transaction sizes is what would be expected of a market. Reasonably small variability in the prices (for example, half of the 45 prices reported from Florida in the second quarter of 1986 were within $4,000 of the median value of $28,000 per kilogram) is a sign of competition among sellers and among buyers in an active market.

These findings are based on analysis only of cocaine transactions. In the data made available to us, there were three cocaine transactions for each marijuana transaction, and while two-fifths of the former represented consummated purchases, only one-fifth of the latter did.

Doubts regarding the quality of the data led to the use of statistics that can be characterized as "robust" (to violations of distributional assumptions) and "resistant" (to the effects of outliers). As a consequence, no formal statistical tests for significance, homogeneity, etc., are presented here. The results presented should be taken as qualitative rather than quantitative.

DATA

The Domestic Intelligence Unit of the DEA provided data on 733 wholesale marijuana and cocaine transactions made between the first quarter of 1985 and the third quarter of 1986. Two types of transactions were reported: agreements where the actual transaction, for various reasons, did not occur ("negotiations") and consummated deals ("buys"). For the cocaine transactions, the negotiation data behave essentially like the buy data, and the two were combined for this analysis.

Table B.1 shows the volume of available data by drug and type of transaction. Table B.2 shows the quarterly cocaine transactions data by transaction type, geographic location, and transaction size. For early 1985 in particular, relatively little data are available for Florida and for the New York Consolidated Metropolitan Statistical Area (CMSA), which must be kept in mind when interpreting the results below.

Table B.1

TRANSACTIONS REPORTED BY DRUG AND TYPE OF TRANSACTION

Type	Cocaine	Marijuana	Total
Buy	234	39	273
Negotiation	317	143	460
Total	551	182	733

Table B.2

COCAINE TRANSACTIONS REPORTED QUARTERLY BY TYPE OF TRANSACTION, LOCATION, AND SIZE OF TRANSACTION

	Quarter							
Item	1st 85	2nd 85	3rd 85	4th 85	1st 86	2nd 86	3rd 86	Total
Type								
Buy	17	17	18	50	26	85	21	234
Negotiation	13	20	20	51	34	122	57	317
Location								
Florida	4	8	10	24	12	45	7	110
New York CMSA	5	8	6	16	14	40	18	107
Balance of U.S.	21	21	22	61	34	122	53	334
Size								
100+ kilos	0	0	1	2	1	4	2	10
10-99 kilos	2	0	4	14	12	38	28	98
1-9 kilos	28	37	33	85	47	165	48	443
Total	30	37	38	101	60	207	78	551

METHODOLOGY

Visual examination of the data shows the anomalies and inconsistencies one would expect, given the genesis of the data. These flaws can be dealt with by either of two methodological approaches.

One approach is to delete or downweight those observations that seem not to follow the pattern of the bulk of the data. This option is most often used to accommodate exogenous information suggestive of anomalous behavior. If, for example, the case records from which these data were abstracted contained indications that certain observations are not "typical" (e.g., negotiations conducted at gunpoint), we could argue on objective grounds that those observations are not to be taken at face value. In the absence of external objective indications of atypical behavior, though, such procedures are dangerously subjective.

The alternative approach is to base the analysis on statistical techniques that are not easily influenced by atypical observations. This is the approach taken here, i.e., examination of medians, quartiles, and other order statistics of the data, disaggregated in various ways (Tukey, 1977, especially Chap. 8). Temporal variation in prices was assumed, since the data span almost a two-year period; therefore, each analysis was disaggregated by calendar quarter. Further disaggregation by transaction type, location, and size of transaction was done separately, so no attempt was made to account for interdependence of these

characteristics. Analysis was largely graphical and hence qualitative in nature. The logical next step would be to fit a multi-way model to the data, including effects for time, location, and transaction type and size. In a classical setting, an analysis-of-variance framework would be appropriate; methods based on medians (Tukey, 1977, Chap. 11) would provide a robust alternative, although again not admitting any formal tests of hypotheses.

The analyses presented below weight each transaction equally, regardless of size, so, for example, a "median price" is the price (per kilogram) of the median wholesale cocaine purchase. The analyses could be duplicated weighting each transaction by the number of kilograms of cocaine represented, so that the "median price" would be the price at which the median kilogram of cocaine was purchased. The meaning of this is unclear, however, since the same cocaine is sold and resold several times in the wholesale distribution chain, each time in smaller units. Only unweighted analyses are presented here.

RESULTS

Figures B.1 through B.3 summarize the results of the analyses graphically and support the conclusions given. Medians and upper and lower quartiles are shown by calendar quarter, and within calendar quarter they are disaggregated by transaction type, location, and size. For each observation, a vertical line connects the median to the two quartiles. Roughly defined, the median price is that value below which one-half of the distribution of observed prices falls. The lower and upper quartiles correspond to the one-quarter and three-quarter points, respectively. Thus the interquartile range—between the lower and upper quartiles—contains half of the observations.

Figure B.1 plots the quarterly cocaine price data by transaction type. There is close agreement between the medians for buys and negotiations and substantial overlap of the interquartile ranges for each period except the first. In each case, a general decline in prices over time (after the first period) is apparent.

Figure B.2 plots the quarterly cocaine price data separately for transactions occurring in Florida, the New York CMSA, and the balance of the country. Here the medians are quite distinct, with Florida generally 10 to 25 percent lower than the balance of the country in the corresponding period and New York between the two. Comparing the Florida data with those for the balance of the country, there is little overlap between the interquartile ranges, confirming the differences between their distributions. Table B.3 shows the interquartile ranges.

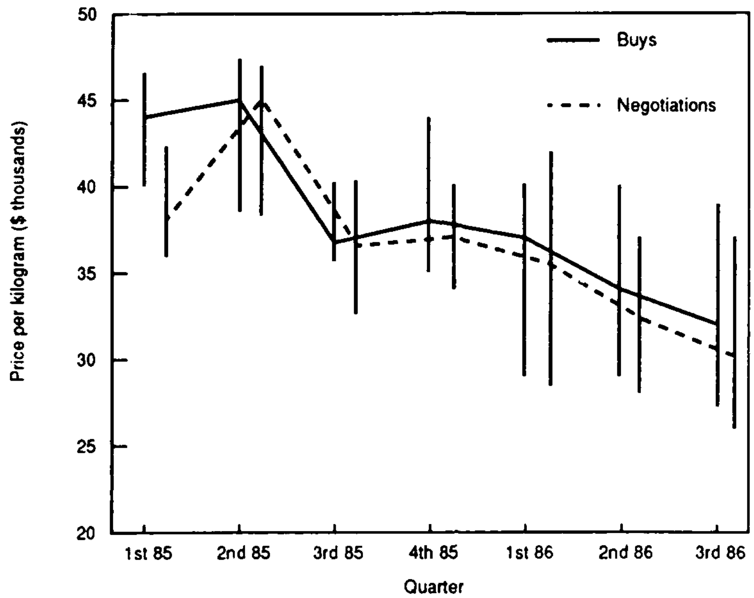

Fig. B.1—Quarterly cocaine price data by transaction type

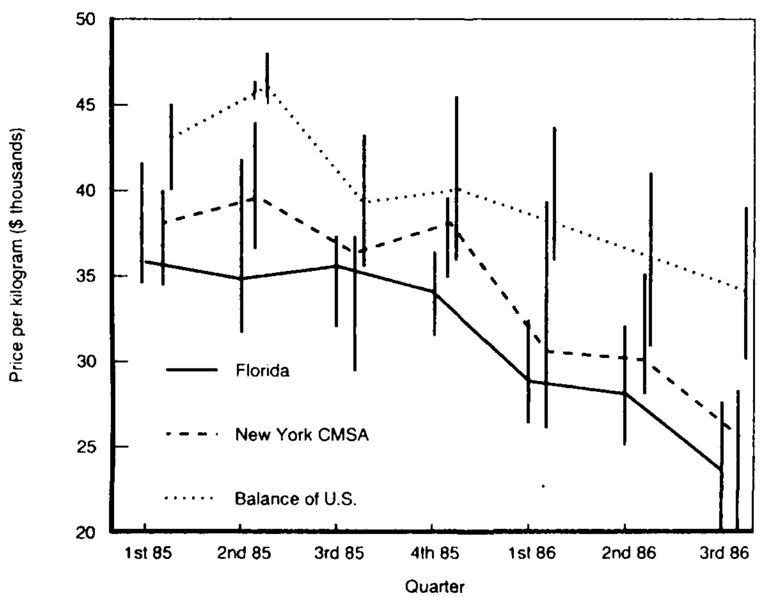

Fig. B.2—Quarterly cocaine price data by geographic area

Table B.3

COCAINE PRICE VARIABILITY: INTERQUARTILE RANGE BY QUARTER AND LOCATION

(In $ thousands)

Item	1st 85	2nd 85	3rd 85	4th 85	1st 86	2nd 86	3rd 86
Florida	7.0	9.9	5.3	4.6	6.1	7.0	7.5
New York CMSA	5.6	9.8	7.9	4.8	13.3	7.0	10.0
Balance of U.S.	5.0	3.0	7.6	9.5	7.7	10.1	9.0
All Data	7.5	8.5	5.2	7.3	12.0	10.7	12.0

The ranges for Florida (especially those from the fourth quarter of 1985 on, when there are a substantial number of observations) are smaller than those for the balance of the country. The reduced variability further demonstrates the relative homogeneity of the Florida data.

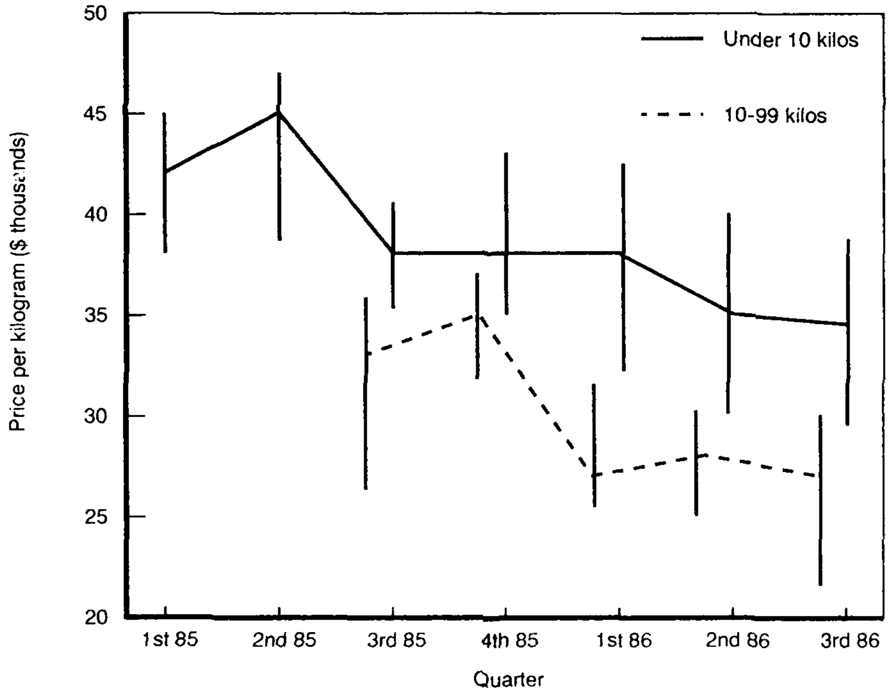

Fig. B.3—Quarterly cocaine price data by size of transaction
(NOTE: Insufficient data are available for 10–99 kilo transactions in the first and second quarters of 1985)

Figure B.3 plots the quarterly cocaine price data separately for transactions of less than 10 kilograms and those of between 10 and 99 kilograms. (The few transactions of over 100 kilograms are not included.) The medians are again generally well separated, with the large transactions lower than the small transactions, and there is little overlap between the interquartile ranges. For example, in the first quarter of 1986, the interquartile range for large transactions spanned \$25,400 to \$31,500, while for small transactions it spanned \$32,000 to \$42,000.

These results are somewhat comparable to those of Pratt, Wise, and Zeckhauser (1979) on price differences in retail consumer markets. Their summary statistics, including the mean and standard deviation, describe prices for 39 products obtained from between 4 and 22 firms. The 39 coefficients of variation (the ratio of the standard deviation to the mean) derived from these data range from 0.04 to 0.71, with three-quarters of them below 0.30. For the cocaine price data, dividing the sample median by 1.35 times the sample interquartile range yields a robust equivalent of the coefficient of variation. For the seven quarters of our aggregate data, these estimates range from 0.16 to 0.54. They are generally larger than those from Pratt, Wise, and Zeckhauser; however, those authors chose uniform products in a limited geographical market, while our data represent a variety of drug purities, transaction locations, and dates.

Appendix C

THE SIMPLE ANALYTICS OF THE EFFECT OF INTERDICTION ON RETAIL PRICES

We begin by assuming two market levels, wholesale and retail. The retailer purchases the product from the wholesaler, adds additional cost, faces enforcement possibilities, and sells the product to the user. The retailer's supply curve is assumed to be the simple sum of the wholesaler's supply curve (S_W) and the additional costs incurred by the retailer (S_R):

$$S(Q) = S_R(Q) + S_W(Q)$$

This construction implies no substitution at the retail level between product and other factors. The derived demand curve facing the wholesaler is then simply the retail demand curve, $P_R = f(Q)$, minus the additional retail costs, S_R. This follows from the equilibrium conditions in the retail and wholesale markets:

$$P_R = S = S_R + S_W; \text{ and } S_W = P_W ,$$

yielding

$$P_W = P_R - S_R .$$

Interdiction at the retail level with an interdiction or loss rate ℓ requires that we denominate quantities in either supplied (Q_S) or delivered (Q_D) terms:

$$Q_D = (1 - \ell)\, Q_S .$$

Since the demand curve is specified in terms of delivered quantities and the supply curves are specified in supplied quantities, we have two alternative formulations:

Delivered quantities:

$$P_R = f\,(Q_D)$$

$$C = f\,(Q_D / (1 - \ell))$$

Supplied quantities:

$$P_R = f\,(Q_S\,(1 - \ell))$$

$$C = f\,(Q_S)$$

Figures C.1 and C.2 plot demand and supply curves that roughly simulate the market. Equilibrium quantity is 125,000 kilograms, demand elasticity is 3.0, and price is \$300,000. Wholesale prices are one-tenth the retail price. Figure C.1 shows the supply and demand curves denominated in supplied quantities, and Fig. C.2 shows them denominated in delivered quantities. Figure C.1 indicates that the demand curve shifts upward as the loss rate goes from 0 to 0.2. Quantity supplied rises from 135,000 to 137,000, while quantity delivered falls to 107,000; price rises from \$300,000 to \$315,000. Changes in the wholesale market are shown in Fig. C.2. From the two figures, it can be seen that the difference between retail and wholesale price increases as interdiction efforts increase.

This formulation ignores the role of smuggler adaptation, since the slope of the supply curve (denominated in delivered quantities) simply swings up proportionately to $1/(1 - \ell)$. Adaptation, to the degree that it is rational, would reduce the supply-curve shift. Thus, the shift shown in the model can be considered the maximum effect interception will have in the absence of adaptation.

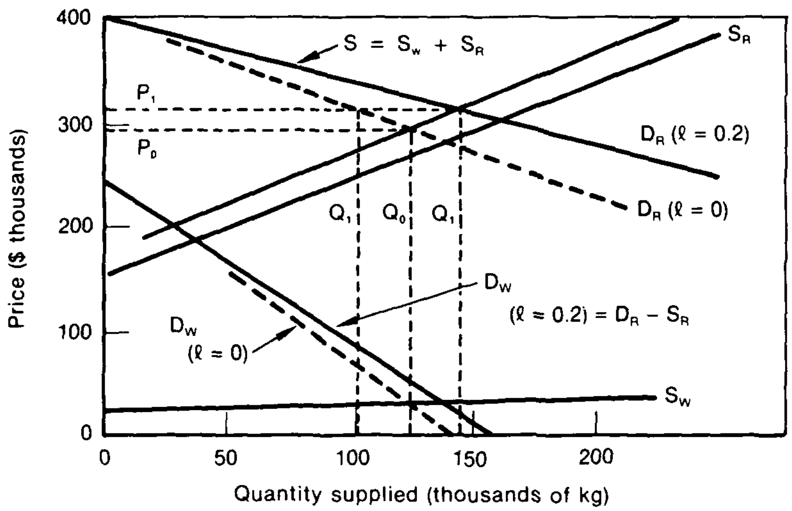

Fig. C.1—Supply and demand curves denominated in supplied quantities

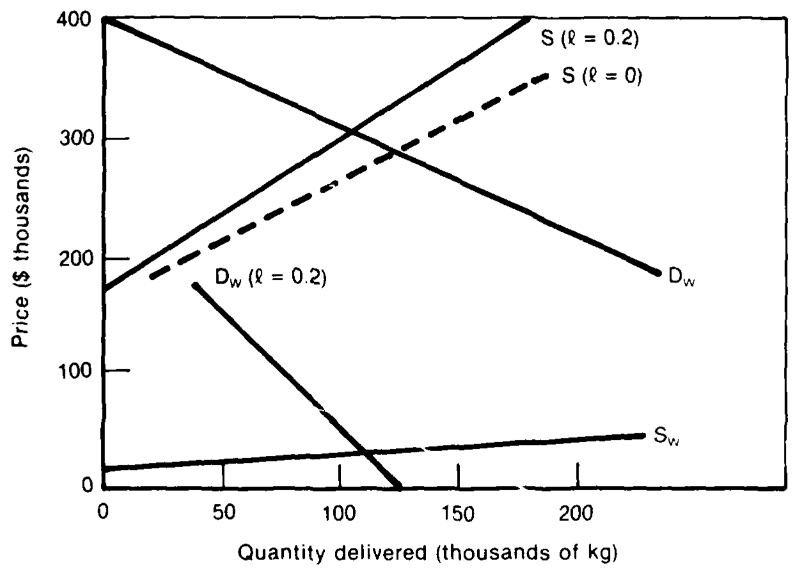

Fig. C.2—Supply and demand curves denominated in delivered quantities

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